THE HAWAIIAN PLANTERS' RECORD

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A monthly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Fern Weevil Parasite

A cable dated from Sydney, May 4, from Mr. Pemberton announces that he has found a parasite on the fern weevil *(Syagrius fulvitarsis)* and has shipped some by the S. S. Makura. This beetle was figured and described in the "Record" for June, 1920, pp. 299–300.

F. M.

Serious Cane Disease Reaches Philippines.

In a recent letter Mr. H. Atherton Lee announces the discovery of the downy mildew *(Sclerospora sacchari)* on sugar cane in the Philippine Islands. Up to the present time he has found this aggressive parasite in one cane field only. The particular field belongs to Japanese planters who imported the seed for planting the field from Formosa in 1920 and there is little doubt but that they imported the disease with the cane.

This disease was introduced into Formosa in 1908 or 1909 with cane cuttings brought from Australia and by 1912 had caused great damage to the sugar industry of Formosa, according to a bulletin issued by their Sugar Experiment Station. A description of this disease may be found in the Planters' Record, 12:257-265,1915.

Cane Seedlings and Bud-selection

There seems to be an impression current that from now on we are going to rely on bud-selection rather than on the growing of seedlings to supply our needs in new cane varieties. This is in reality far from the truth, for the rearing of choice seedlings and the application of bud-selection are two separate phases in the production of superior varieties of cane.

We must first grow seedlings in order to secure the many constitutional

varieties which our varied conditions require, then by bud-selection we can isolate in each of these varieties the superior strains.

No one would advocate an attempt to isolate a drought-resisting cane from H 109 by bud-selection, nor would they, by the same means, seek to isolate a strain from Striped Tip for culture at low elevations under irrigation.

We still rely on seedlings to supply our new varieties and on bud-selection to raise each new variety to its highest possible standard.

Experiments in Cane Planting.*

"In a report of different experiments in cane planting conducted in the island of St. Croix, West Indies, it was found that over an average of eight plots, cane grown from first ratoon plants gave an average of 54.8 tons per acre, as against 41.8 tons for plant cane cuttings, and 34.3 from those obtained from second ratoons. The variation, however, was greater in the case of the ratoon cuttings, namely, from 38.8 tons to 52.2; whereas in the case of plots derived from plant crops, the highest tonnage was 45.3, and the lowest 35.6 tons, being a difference of only 9.7 tons, as against a difference of 13.4 tons where first ratoons were used."

A similar experiment harvested at Wailuku two years ago, comparing seed from plant, ratoon, and cut back cane, showed results in favor of seed from ratoons.

R. S. T.

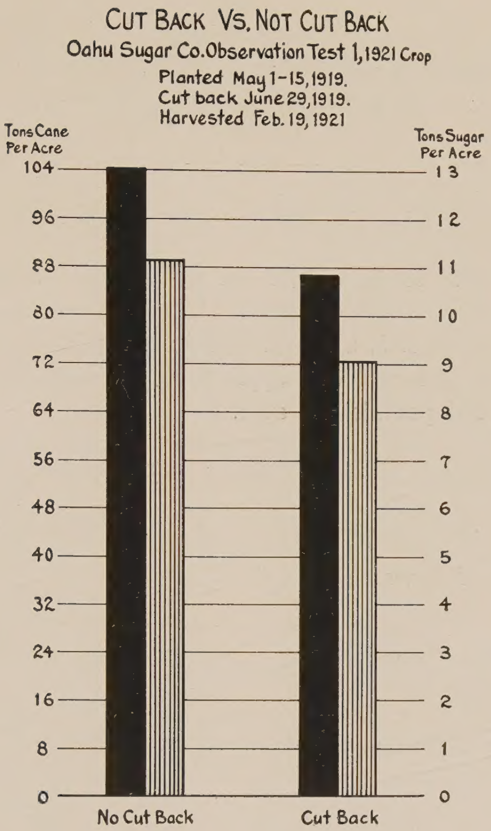
Cut Back Versus Not Cut Back.

In June, 1919, Oahu Sugar Company, field 15, had an excellent stand of dark green, vigorous growing H 109 plant cane. Planting took place from May 1 to 15. The cane received normal necessary irrigation, and on June 29 stood from 3 to 4 feet high. The elevation of the field ranged from 200 to 300 feet above sea level.

Then arose the question of cutting back. It was finally decided not to cut back the field, so an observation experiment was put in to see what would have happened had the field been cut back.

The experiment consisted of a narrow strip of plots, one watercourse

* From Queensland Agr. Jour., Vol. XV, p. 76, Feb. 1921.



in width, extending from the bottom to the top of the field. Every alternate plot was cut back. With the exception of cutting back, all plots received identical treatment.

At time of tasseling in the following December, not a tassel appeared in any of the plots.

During the first year of growth, there was a marked difference in appearance between the two sets of plots, the cut back being decidedly inferior in size of cane to the others.

During harvesting of the field, a few of the plots were harvested with the following results:

Plot	Yields—Tons per Acre			Loss Due to Cutting Back	
	Cane	Q. R.	Sugar	Cane	Sugar
Not Cut Back	104.24	9.35	11.14	.....	.....
Cut Back	86.93	9.58	9.07	18.31	2.07

In other words, if the field had been cut back it would have suffered a loss of 18.31 tons of cane or 2.07 tons sugar per acre. R. S. T.

Second Season Fertilization.*
Amount to Apply.

ONOMEA SUGAR CO. EXPERIMENT NO. 5, 1921 CROP.

This experiment is to determine the economical amount of nitrogen to apply during the second growing season. The first season a uniform dose of 88 pounds of nitrogen as B 5, a mixed fertilizer, was applied to all plots, while in the second season nitrogen was applied in the same form at the rate of 0, 44, 88, 132, and 176 pounds per acre.

The results show gains up to 132 pounds of nitrogen applied the second season, the latter amount causing a gain of 7.45 tons of cane or .53 ton sugar over no nitrogen. For the larger amount, 176 pounds, there is a further slight gain in cane, but the poorer juices cause a loss in sugar. The average yield for each treatment is as follows:

Plot	Treatment—Pounds Nitrogen		Yields—Tons per Acre			Gain over No N. During 2nd Season	
	1st Season	2nd Season	Cane	Q. R.	Sugar	Cane	Sugar
A	88	0	37.36	7.58	4.92	....	....
B	88	44	37.62	7.56	4.98	0.26	0.06
X	88	88	43.31	8.40	5.16	5.95	0.26
C	88	132	44.81	8.23	5.45	7.45	0.53
D	88	176	45.98	8.53	5.39	8.62	0.47

This experiment has now been harvested for three consecutive crops, the only variations being in the form in which the nitrogen was applied. In the first crop the second season nitrogen was applied as nitrate of soda, while for the past two crops it has been applied as B 5, a mixed fertilizer containing 11% N. 8% P_2O_5.

In the first crop,‡ on first ratoons, the profitable limit was found to be 132 pounds the second season, the increased yield over and above no nitrogen being 13.78 tons cane or 1.57 tons sugar. The 176 pounds of nitrogen gave a slightly greater yield of both cane and sugar but not enough more to repay the cost.

In the second crop,† on second ratoons, the gain from 132 pounds of nitrogen amounted to but 2 tons cane or .33 ton sugar. The 176 pounds of nitrogen gave a further increase to 3.9 tons cane but the poor juices caused no increase in sugar.

* Experiment originally planned and laid out by L. D. Larsen.

‡ Record, Vol. XVI, p. 346.

† Record Vol. XXI, p. 232.

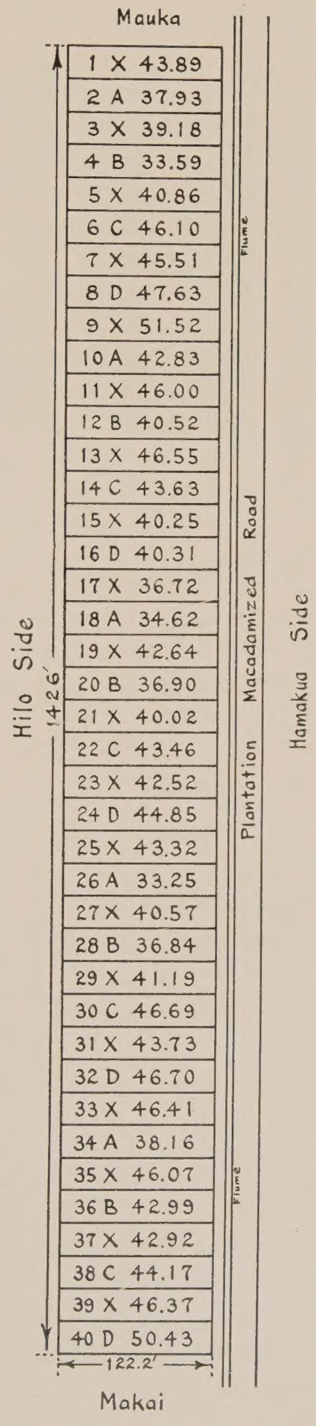
Amount To Apply Second Season

Onomea Sugar Co. Exp. 5, 1921 Crop

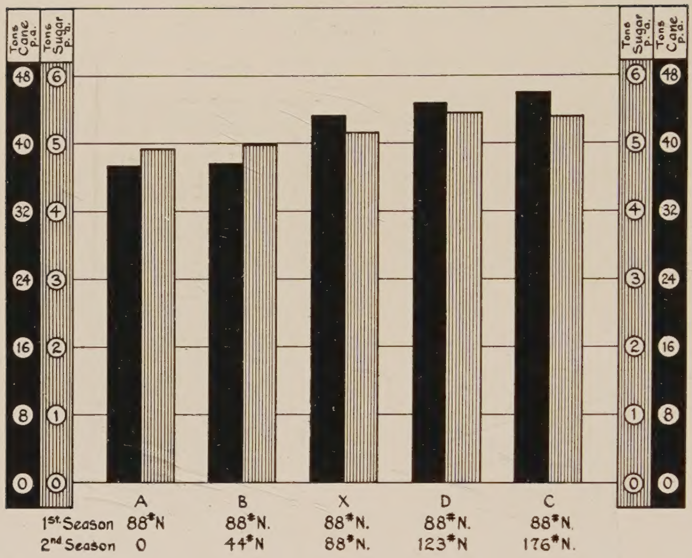
Field 35.

Summary of Results

Plots	Treatment 1st Season	Treatment 2nd Season	Yields – Tons Per Acre: Cane	Q.R.	Sugar	Gain or Loss Over Adjoining X Plots: Cane	Sugar
A	88# N.	0	37.36	7.58	4.92	- 6.27	- 0.27
B	88# N.	44# N.	37.62	7.56	4.98	- 4.98	- 0.09
X	88# N.	88# N.	43.31	8.40	5.16	0	0
C	88# N.	132# N.	44.81	8.23	5.45	+ 1.82	+ 0.33
D	88# N.	176# N.	45.98	8.53	5.39	+ 1.94	+ 0.15



AMOUNT TO APPLY SECOND SEASON
ONOMEA SUGAR CO. EXP. 5, 1921 CROP
FIELD 35.



In the third crop, on third ratoons, the gain from 132 pounds of nitrogen amounted to 7.45 tons cane or .53 ton of sugar. The 176 pounds of nitrogen gave a further increase in yield of cane to 8.62 tons but the poorer juices caused a decrease in the sugar yield.

The yields of sugar for each treatment for the three crops are summarized in tabular form as follows:

Treatment		Tons Sugar per Acre		
1st Season	2nd Season	1917 Crop	1919 Crop	1921 Crop
88 lbs. N.	0	6.21	6.15	4.92
88 lbs. N.	44 lbs. N.	6.72	6.04	4.98
88 lbs. N.	88 lbs. N.	7.35	6.29	5.16
88 lbs. N.	132 lbs. N.	7.62	6.48	5.45
88 lbs. N.	176 lbs. N.	7.87	6.47	5.39

In looking over these figures we see that much larger gains for increasing amounts of nitrogen were obtained in the 1917 crop than in either of the two succeeding ones. This is probably due to the fact that the fertilizer applied during the first season to the 1917 crop contained 4½% of potash. Eight hundred and twenty pounds of fertilizer were applied, thereby supplying 37 pounds of potash. The Onomea soils respond to potash in a marked manner. The fertilizer applied to the 1919 and 1921 crops contained no appreciable amounts of potash. It is therefore reasonable to assume that the nitrogen applied to the 1919 and 1921 crops could not be utilized to full advantage on account of lack of sufficient potash.

DETAILS OF EXPERIMENT.

Object:

To determine the most economical amount of nitrogen to apply in one dose in the second growing season.

Location:

Field 35 on Hilo side of Macadam road.

Crop:

Yellow Caledonia, third ratoons, long.

Layout:

Number of plots: 40.

Size of plots: 1/10 acre each, consisting of 6 furrows each 5.94 feet wide and 122.2 feet long.

Plan:

First season fertilization uniform to all plots at rate of 800 pounds B 6 per acre, in two equal doses.

Second season, B 5 applied in one dose as follows:

Plot	Lbs. B 5 per Acre
A	0
B	400
X	800
C	1200
D	1600

B 6=11% N. (4½% nitrate, 4½% sulfate, 2% organic).

PROGRESS OF EXPERIMENT.

July, 1919—Last crop harvested.
July 30, 1919—Experiment off barred.
August 8, 1919—First fertilization, 400 pounds B 6 per acre.
November 20, 1919—Second fertilization, 400 pounds B 6 per acre.
April 6, 1920—Third fertilization according to schedule, using B 5 instead of B 6.
February 25, 1921—Experiment harvested by W. L. S. Williams.

R. S. T. AND J. A. V.

Fertilizer Experiment—Number of Applications.

WAIPIO EXPERIMENT S.—1921 CROP.*

This experiment is to determine in how many applications a given amount of fertilizer should be applied. A total of 270 pounds of nitrogen was applied in one, two, and three doses in each of the two growing seasons, making a total of two, four, and six applications per crop to both the D 1135 and H 109.

All nitrogen was applied in the form of nitrate of soda according to the following schedule:

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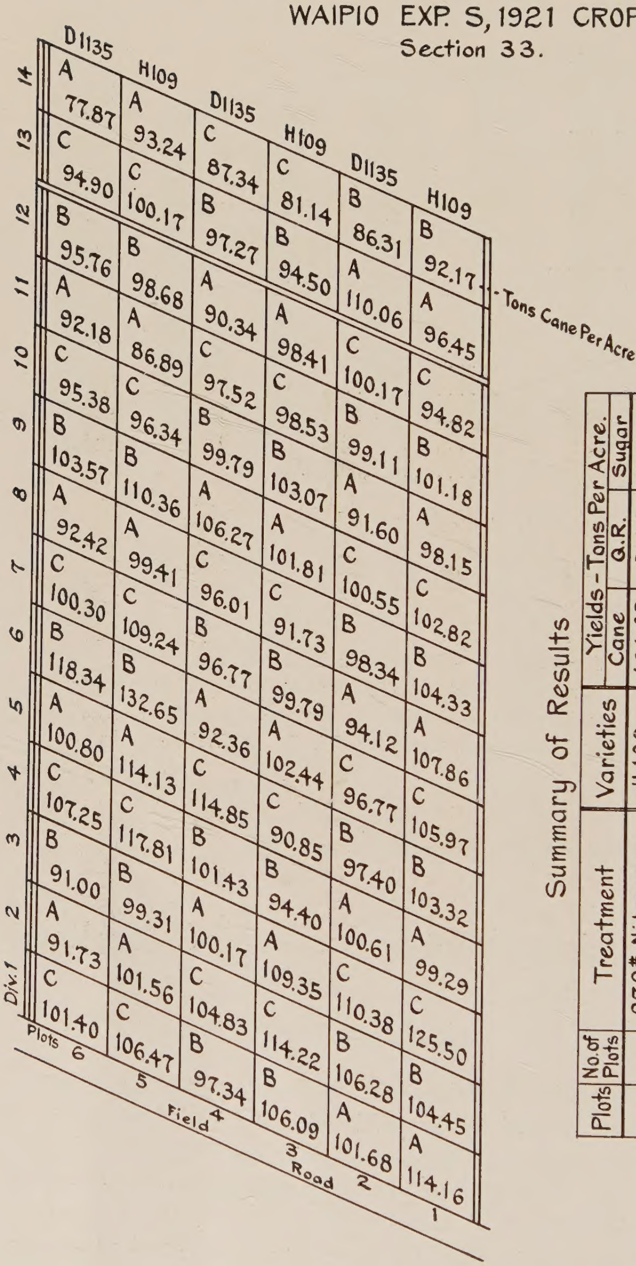
* Experiment planned by J. A. Verret. Results computed by R. S. Thurston and F. A. E. Abel.

FERTILIZER-NUMBER OF APPLICATIONS

WAIPIO EXP. S, 1921 CROP

Section 33.



Summary of Results

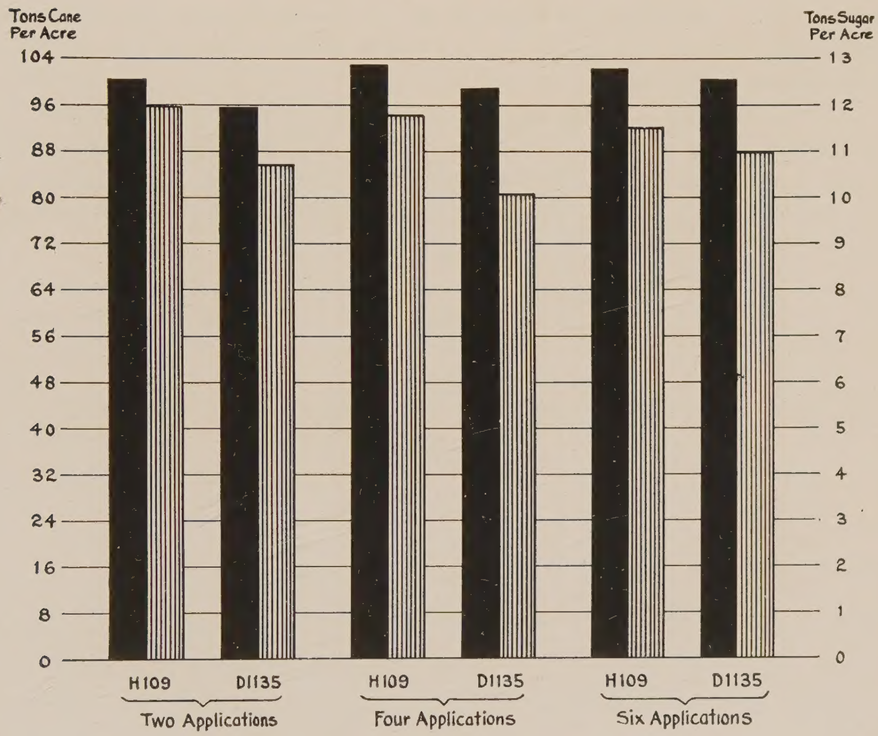
Plots	No. of Plots	Treatment	Varieties	Yields—Tons Per Acre. Cane	Q.R.	Sugar
A	28	270# Nitrogen Two Applications	H109	101.65	8.48	11.99
			D1135	95.87	8.96	10.70
B	28	270# Nitrogen Four Applications	H109	103.16	8.75	11.79
			D1135	99.19	9.84	10.08
C	28	270# Nitrogen Six Applications	H109	102.54	8.89	11.53
			D1135	100.55	9.16	10.98

Plots	Number Plots	Fertilizer in Pounds N. S. per Acre						Total Lbs. N. per Acre
		Sept. 1919	Nov. 1919	Dec. 1919	Feb. 1920	April 1920	May 1920	
A	28	1160	0	0	580	0	0	270
B	28	580	580	0	290	290	0	270
C	28	387	387	387	193	194	193	270

FERTILIZER - NUMBER OF APPLICATIONS.

WAIPIO EXPERIMENT S, 1921 CROP

Section 33.



When the yields of the two varieties are averaged for each treatment, the best sugar yields are obtained by applying the fertilizer in two doses, one each season. Applying it in two or three doses each season gives slightly increased cane yields but the poorer quality ratio causes a loss of at least .4 ton of sugar. (The better Q. R. of the C plots over the B plots is undoubtedly due to inaccuracy of sampling.) The average yields are as follows:

Plot	Number Plots	No. of Fertilizations		Yield—Tons per Acre		
		1st Season	2nd Season	Cane	Q. R.	Sugar
A	28	1	1	98.76	8.71	11.34
B	28	2	2	101.17	9.26	10.93
C	28	3	3	101.54	9.02	11.26

When, now, the yields of the two varieties are considered separately, H 109 is found to give practically the same tonnage of cane whether the fertilizer be applied in two, four, or six doses, divided equally between the seasons. But the larger number of applications causes a definite inferiority in the quality ratio, thus causing a definite and appreciable loss in yield of sugar. Thus, applying the fertilizer in six doses, besides the extra cost of application, causes a loss of .46 ton sugar when compared with the yield from two applications.

In the case of D 1135, the larger number of applications causes a pronounced increase in weight of cane, but not sufficient to overcome the loss caused by inferior juices, so the final result is in favor of two doses rather than four or six. The yields obtained by varieties are shown below:

H 109

Plot	Number Plots	No. of Fertilizations		Yields—Tons per Acre		
		1st Season	2nd Season	Cane	Q. R.	Sugar
A	14	1	1	101.65	8.48	11.99
B	14	2	2	103.16	8.75	11.79
C	14	3	3	102.54	8.89	11.53
			D 1135			
A	14	1	1	95.87	8.96	10.70
B	14	2	2	99.19	9.84	10.08
C	14	3	3	100.55	9.16	10.98

These results corroborate those obtained in the past and give further evidence showing that one application of fertilizer the second season is more profitable than two or three.

DETAILS OF EXPERIMENT.

Object:

To test the most profitable number of applications in which to apply a given amount of fertilizer.

Location:

Waipio, Section 33.

Crop:

D 1135 and H 109, fourth ratoons, long.

Layout:

Number of plots: 84.

Size of plots: 1/30 acre net, each plot composed of 8 lines.

Plan:

Plot	Number Plots	Fertilization—Pounds Nitrogen per Acre						Total Lbs. N.
		1st Season			2nd Season			
		Aug. 1919	Oct. 1919	Nov. 1919	Feb. 1920	April 1920	June 1920	
A	28	180	..	..	90	..	..	270
B	28	90	90	..	45	45	..	270
C	28	60	60	60	30	30	30	270

PROGRESS OF EXPERIMENT.

June 9, 1919—Last crop harvested.
September 2, 1919—First fertilization.
November 6, 1919—Second fertilization.
December 19, 1919—Third fertilization.
February 4, 1920—Fourth fertilization.
April 19, 1920—Fifth fertilization.
May 18, 1920—Sixth fertilization.
March 1–16, 1921—Experiment harvested by F. A. Paris and F. A. E. Abel.

[R. S. T.]

Cyrtorhinus in Hawaii and Some Factors Acting Against It.

By F. Muir.

The first colony of *Cyrtorhinus mundulus* was liberated on the 12th of July, 1920, and a few more on the 19th. These were known to have produced one generation in the field, and after that they seem to have disappeared. Since then a number of colonies have been turned loose on Oahu and Hawaii, and they have maintained themselves for some five or six generations, but they have not increased or, so far as we have discovered, distributed themselves to any extent. This has been a disappointment, as observations in Australia and Fiji led us to judge that it would increase and spread without much difficulty.

In our cages, where climatic conditions are quite natural, *Cyrtorhinus* increases very rapidly, although the egg-parasite of the leafhopper *(Paranagrus optabilis)* is quite numerous. This indicates that it is neither climatic conditions nor the egg-parasite that is inimical to it. In going through the cane fields and observing the various species of insects which might attack *Cyrtorhinus* in the young and adult stages, our attention is soon attracted to the "Kissing bug," *Zelus renardii.* This insect is described and figured in Entomological

Bulletin No. 1 (1905), part 7, page 232, plate XVI, figures 1, 2 and 3, under the name of *Zelus peregrinus*.

When leafhoppers were very numerous it was considered as beneficial, as it attacked them, but it was also recognized as doing harm by attacking lady-bugs and other beneficial insects.

During 1919–1920 a little lace-wing fly from Australia *(Micromus vinaceus)*, which feeds on Aphis, was liberated in hundreds in some of the fields where the *Cyrtorhinus* have been liberated, but they all eventually disappeared. *Zelus* was found to prey upon them.

It thus appears that the evidence for and against *Zelus* in our cane fields is divided, but gradually I have come to the decision that we would be better without it, or in much lesser numbers.

Zelus renardii is a Californian insect which found its way into Honolulu previous to 1897 and has gradually spread over the whole of the archipelago.

In California there are five species of this genus, none of which ever become so plentiful as *Z. renardii* does in Hawaii. That they are kept in check by insect parasites is the most natural conclusion, and egg-parasites are the most probable, although I know of no parasites being reported from them. It may be worth our while to make inquiries along this line and to experiment with any parasites found to occur in California.

Present Investigations of the U. S. Bureau of Soils.

By W. T. McGeorge.

It will be remembered that some years ago the Bureau of Soils created quite a stir in soil science, fertilizer, and plant food investigations on its presentation, through the channels of its own bulletins and the columns of the scientific press, of the toxin theory of plant excretions and the claim, based upon experimental data, that the soil solution was not increased by the addition of mineral fertilizers to the soil. In other words that the concentration of the soil solution was a constant.

While these theories have been more or less modified, their effect upon the trend of soil investigations has been of unquestionable value in that it has created more diversified lines of investigation. Undoubtedly, up to this period, it was assumed, too generally, that fertilizer applications acted solely as an additional source of plant food. While certain of this work has been transferred from the Bureau of Soils to the Bureau of Plant Industry, it is nevertheless of interest to note the nature of the activities at present occupying the interest of this Bureau as covered in their recent annual report.

Of their chemical investigations two lines stand out prominently: 1. Anticipating the limitations of the regular chemical analysis of soils they have

sought other means of ascertaining the composition of the soil. Particularly the actual crystalline form of the soil constituents. They have treated soils in one ton lots. Results thus far indicate that the salts occurring in the soil solution are of the same general type as the Strassfurt deposits in Germany and of other deposits formed by the evaporation of inland lakes. In view of the fact that the soil is originally the source of these deposits, in that they have been formed from the drainage and run-off water, their conclusion seems justified. Sufficient progress has been made to show that the different soil types, however, support salts of varying composition in their soil solution. Additional variation results from the use of fertilizers, temperature, and other factors.

2. In working upon these large lots of soil they were able to isolate appreciable amounts of colloidal material or ultra-clay. This substance appeared to be a silicate of aluminum with some iron and traces of magnesium, calcium, potassium, and sodium, probably absorbed. It is upon this substance that the soil depends for its plasticity, as on separating it from the soil it loses its plastic properties. Ten per cent of this substance mixed with sand will dry into briquettes with a crushing strength greater than an equal amount of Portland cement. Yet on placing the briquettes in water they completely disintegrate. This colloidal material was found to possess a very high absorbing power and in a dry state will absorb as much ammonia gas as will charcoal.

The significance of the above to local conditions is very apparent. In the wide variation of our soil types, fertilizer applications, altitude, rainfall, temperature, and other climatic factors, there probably exists a corresponding variation in the composition of the soil solution, and especially the ratio between the elements dissolved therein. What relation this may have to variation in the yield of sugar throughout the islands, or even on the same plantation, can as yet only be conjectured. Regarding the isolation of the colloidal substance conducive of plasticity, attention has been frequently called to the high iron and alumina content of Hawaiian soils. Also the excessive plasticity imparted to local soils by the presence of these elements in amounts many times in excess of that present in mainland soils. The ratio between these two elements varies considerably and it has been noticed that a higher alumina content is usually accompanied by a more colloidal soil structure. It is to this property that we must ascribe the high fixing power of Hawaiian soils. The absence of any harmful results from the continual heavy application of commercial fertilizers in the islands is probably closely related to the presence of this plastic substance.

Another point of local interest in this report is that covering the use of the so-called concentrated fertilizers, such as ammonium nitrate and ammonium phosphate. The effect of cyanamid in mixed fertilizers when it was first introduced to the trade is still fresh in our memory. They therefore advise careful investigation of the properties of these materials before adopting their use. Theoretically and economically they are admirably suited for use as fertilizers. The saving in transportation to isolated localities is worthy of serious consideration.

They advise the following lines of study: 1. The chemical and physical properties of the compounds and the mixtures it is proposed to use in mixed

fertilizers; 2. the compatibility of these compounds in mixtures; 3. limits in which they may be mixed without alteration in composition; 4. properties which interfere with their storage, handling, and transportation; 5. methods for obviating these properties; 6. suitable methods of application.

The supply of fertilizing materials of this nature is of course partly dependent upon the attitude of Congress toward the maintenance of the several large plants constructed as a war measure for the manufacture of nitrogen compounds from the air and of the commercial interests towards the new process proposed by the Bureau of Soils for the manufacture of phosphoric acid by volatilization in the electric furnace. A plentiful supply of basic ammonia is imperative if this substance is to be adopted as a neutralizing agent for the phosphoric and nitric acids supplied by the above processes.

Top-Rot of Cane and Lightning Injury.

By C. W. Carpenter.

The top-rot disease of cane is, as its name implies, a rotting of the top and growing point of the cane stalk. From time to time we have specimens of top-rot sent in for examination, and it has been the custom, in the absence of proof as to the cause of the trouble, to assume that this was in every case infectious top-rot. Since a serious disease of this nature has been reported locally as well as in other countries, we have recommended that where top-rot sets in, all diseased cane be at once cut and burned as a precautionary measure.

It is the purpose of this paper to record certain observations on top-rot of cane as a result of lightning injury. During the past two years specimens of cane showing top-rot symptoms have been received and examined, and several spots of cane in the field affected with an obscure trouble have been investigated. Nothing definite has been seen indicating that this top-rot is infectious in nature. Observations have been made by various members of our staff, as well as by plantation men, indicating that the top-rot in all these cases is a result of lightning striking in the cane field. The rot does not spread beyond the area originally injured, though there is a suggestion of spreading, since the most seriously injured cane in the middle of the spot rots first. The evidence supports the view that the cane tops were rotting as a natural sequel to death from some external factor.

In 1914 Jones and Gilbert[1] called the attention of pathologists to the subject of lightning injury to herbaceous plants, particularly cotton and potato. In a later paper these writers[2] state that there have been several reports of light-

[1] Jones, L. R., and Gilbert, W. W. Lightning injury to cotton and potato plants (Abstract). *In* Phytopath., Vol. IV, p. 406. 1914. Two plates.

[2] Phytopath. Vol. VIII, p. 270–282.

Fig. 1. Lightning injury of cane. Note the shredded top leaves of the stick in the center.

ning injury in each of the following crops: cotton, potato, tobacco, and sugar beets; and single reports for kale, alfalfa, ginseng, onion, tomato, cucumber, Indian corn, and sugar cane. In the case of the last two crops the evidence is noted as less conclusive. Concerning the types of injury we may quote Jones and Gilbert at some length (l. c. p. 281):

> "In respect to description of the injuries, while there is some variation in details, there is a surprising amount of likeness as to the general characters. Certain things have been reported upon enough to merit review. In general the killed areas vary from 10 to 30 feet in diameter and are roughly circular in outline. Where much larger areas or irregular extensions have been noted, it has been suggested that the distribution of the damage was probably associated with the presence of surface water. As suggested in our earlier article it seems possible, and at least justifiable as a working theory, that the greatest damage results when the lightning stroke occurs soon after the rain begins. According to this theory the drier soil below the surface would then favor the wider diffusion of the shock through the recently wet or flooded surface layer. In general the killed areas are sharply delimited, although the margins are somewhat ragged and there is a narrow zone of partially killed or weakened plants.
>
> "In most cases there is little or no evidence of mechanical disturbance at the surface of the soil, although certain observers make definite report of a small, crater-like depression at the center of the disturbed area. Probably this is not a constant feature, and in any case the amount of dislocated soil is so small that the accompanying rain would generally obscure or obliterate the evidence. With herbaceous plants there seems little mechanical splitting or tearing of the injured tissues. It seems possible that in the few cases where this is reported (potato, sugar cane) it may represent a splitting due to the sharp bending and the shrinkage of the stems after injury rather than an actual rending by the electric discharge."

Jones and Gilbert (p. 282) explain the lightning injury phenomena in the following language:

> "When an electric storm breaks suddenly following a period of dry weather, and the first rain wets the top soil, there remains a layer of dry earth between this wet surface and the moist soil underneath which is a poor conductor of electricity. When the lightning strikes the wet surface soil it disperses in all directions horizontally and then downward, following lines of least resistance. The plant stems and roots with their abundant water content are better conductors than the layer of dry soil just mentioned and so the electrical current passes through them. The tissues may thus be variously injured or killed, depending upon the amount of current passing through them. The strength of the current, of course, diminishes the farther it gets from the center of the affected spot, and consequently the lessened injury at the margins of the area. In some cases apparently the discharge may be broken and strike in several spots near together."

Fig. 2. Part of a stick struck in the middle. The top was not visibly affected, but the stick was neatly stripped of leaves below the injury.

In cane, as we have observed the evidence, the injury appears to be direct rather than diffused through the wet soil killing the roots. The diffusion appears on the contrary to be over the wet surface of the leaves, the dry cane trash below serving as a non-conductor in some degree.

Stevenson[1] records an observation of lightning-injured cane, a type of injury which he says is apparently rare. The area was circular and about a rod in diameter, sharply set off from the surrounding mature cane. In the affected area only a few dead stalks remained, some broken off a few feet above the ground. There had been no growth of new shoots, and the stools were dead. Charred bits of cane trash were found which, combined with other evidence, suggested lightning as the cause. Stevenson stated that no other source of fire could have destroyed green cane so completely, especially the underground portions of the stools. He does not mention top-rot in this connection, and this symptom, if present at first, was doubtless not existent at the time he saw the spot.

The symptoms of the top-rot disease of cane are outlined below. It does not seem necessary to take up the finer details of description, since this has already been done in Pathological Circular 5, certain paragraphs of which are quoted below.

In the disease as it has come to our attention, the top of the spindle is rotted and soft at its base, the top being readily pulled out. The leaves are at first tinged purple on the exposed surfaces and somewhat lacking in turgor. They later dry up, the top joints shrink markedly and the soft, ill-smelling rot proceeds downward, accompanied by the usual discoloration of fermenting cane sticks. It is a top-rot and nothing as to its cause in Hawaii has been determined, though numerous suspected organisms have been investigated.

That the disease as described by Cobb had much in common with what we are now discussing is shown by a few paragraphs quoted from his paper:

> "The attacks are more likely to come to the attention of the grower after rainy spells than at any other time,

[1] Stevenson, John A. Lightning injury to cane. *In* Phytopath. Vol. VII, p. 317–318. One plate. 1917.

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as such weather is more favorable to this disease. In pronounced cases the plants over considerable areas, which may up to that time have done well, will lose color at the top and change in appearance rapidly, the leaves becoming yellowish or reddish, then ashen. The odor of the disease begins to be perceptible at about this time; that is, at the time when the tops are no longer green. On taking hold of the top of a diseased stalk, it will break off and easily pull loose, and at the broken part the nostril will detect, if it has not already done so, the pig-sty odor that is characteristic of the disease. This is so pronounced as to be noticeable in the field in calm weather at some little distance from the diseased plants. Stalks of cane several months old often retain their normal appearance at the base even after the tops have died, but it is not long before this part of the cane becomes diseased also. Ultimately the whole stalk dies. Outwardly the most striking appearances on the stalk are the marked shrinkage in the upper internodes. This is so pronounced that in the case of the upper and most sappy internodes the surface falls in, so that in places the curvature of the surface is reversed, becoming concave instead of convex. All this may occur on the stalk without its losing its normal color.

"If one of the stalks be split in halves from end to end, some of the most pronounced lesions of the disease are brought to view. It will be at once noted that the most pronounced symptoms are located at the top of the stalk, fully justifying the name *Top-Rot*. Below the base of the arrow, that is, at the top of the stalk where the younger leaves originate, and at the point where, as it has been already noted, the top easily pulls loose, is a cavity in the stalk. If the disease is well advanced this cavity is filled with a brownish or yellowish, offensive looking, and even more offensive smelling, slime. There may be more than one of these cavities, but there is one, coincident with the base of the upper group of shortest internodes, that is somewhat different from all the others, supposing any others to be present. This cavity may not be the largest, but it is that in which there is usually the largest amount of slime in the most offensive state. * * * * * * *

"There is no evidence to show that *Top-Rot* is easily spread. It is uncommon for it to affect large areas, and, so far as can be judged at present, it is seldom destructive in Hawaii except after unfavorable weather—that is, long continued rain."

In January, 1920, Mr. R. S. Thurston called attention in his notes to several patches of diseased cane on Kauai in the following language:

"In field 36 there is an area of about 1/20 acre in which the Yellow Caledonia cane has turned yellow and the tops of the larger sticks have rotted. In some cases just the center has rotted out, while the older leaves look normal. In other cases the older leaves have a dark reddish purple hue, near their tips, this color extending for quite a distance down the midribs. I have never seen anything like it before.

"Mr. Broadbent showed me a spot here on Grove Farm where the cane is diseased the same as at Kilauea. In the past few days six such spots have been discovered here. In at least four of the cases a peculiar circumstance is that at about the center of these spots there is a hole in the ground about 12 to 18 inches in diameter and 6 inches deep. And near this hole all the leaves are covered with dirt, the dirt having lodged between the leaf blade and the stalk. In these spots the dead centers and purple leaves are present, the same as at Kilauea. This would seem to indicate that these spots were struck by lightning."

On April 29, 1920, Mr. W. L. S. Williams discusses in his notes similar diseased areas on the Island of Hawaii, as follows:

"Top-Rot epidemic. Outbreaks of top-rot are now reported from Papaaloa and I have seen one at Hakalau which appears to be just starting. I am beginning to incline to the theory that these centers of infection are due to lightning in the storm of March 29–30. For one thing the cane leaves appear burned and discolored, aside from the spots and blotches caused by the disease. In the second place I noticed at Pepeekeo in a field where the trash had been burned off that some large suckers that had been in contact with the flames bore the same markings and that the centers had decayed similarly with the centers of canes affected with top-rot. The characteristic odor was also present. * * * * * * The disease might have got its start in the canes when in this weakened condition, or it may be that the fermenting of burned cane causes an odor that is similar to the top-rot odor. This does not explain the apparent ability of the disease to spread to healthy canes though."

The writer visited some of these diseased areas on Hawaii April 29 to May 2, 1920. At Papaaloa, in Field 8 of the Laupahoehoe Sugar Company, second ratoon, D 1135, five to six feet high, at an elevation of 1250 feet, a spot of sick cane about 50 feet in diameter was seen. The following is extracted from a trip report at the time:

"The affected cane could be remarked at considerable distance, owing to the peculiar seared appearance, in contrast to the healthy cane surrounding it.

"On closer examination it was found that the leaves of many of the plants were somewhat lighter colored than normal and with a varying portion of the tips or mid portion of the exposed surface tinged a peculiar mottled purple color. This color in general was most prevalent in the plants near the center of the affected patch, and here, too, a number of 'top-rot' plants were found. The central portion of the plant was readily removable, the spindle being a purulent rotting mass with a vile odor. In general the 'top-rot' plants were in the central part of the diseased spot. The top internodes did not show the shrinkage characteristic of infectious top-rot. Outside of this area or in the

Fig. 3. This stick was struck at the top and the leaf-sheaths below the mid-portion remained intact before bringing to the laboratory. The bolt jumped to the middle part of the stick shown in Fig. 2.

border zone the plants showed a grading off in the purpling effect. Plants shorter than the normal, often as if by protection of the larger plants, escaped entirely. Those plants not showing the top-rot appear to be growing away from the disease, as the central leaves are healthy. It is the fifth leaf, etc., from the top which shows the purpling effect. The significant thing of interest to me in this case is that we have as an associated symptom with 'top-rot' a purple coloration of the foliage more or less extensive on those surfaces which must have been the uppermost exposed surfaces of the top leaves a few weeks ago.

"Two more similar spots of cane were pointed out to me at Papaaloa, one in mature Demerara 1135 in Field 9 and one in Field 3 in Yellow Tip cane. The latter does not show as marked purpling nor as extensive disturbance as the others mentioned. There was very little top-rot in either of the two latter.

"The spots were first noticed about a month ago and it is recalled that there was a severe electrical storm about that time. The symptoms of the disease and the relation to the storm recall the very similar, if not identical, trouble at Kilauea and Grove Farm Plantation in January. The Demerara at Kilauea is said to have grown away from the trouble."

The following impressions are quoted from a report dated June 28, 1920, in answer to an inquiry:

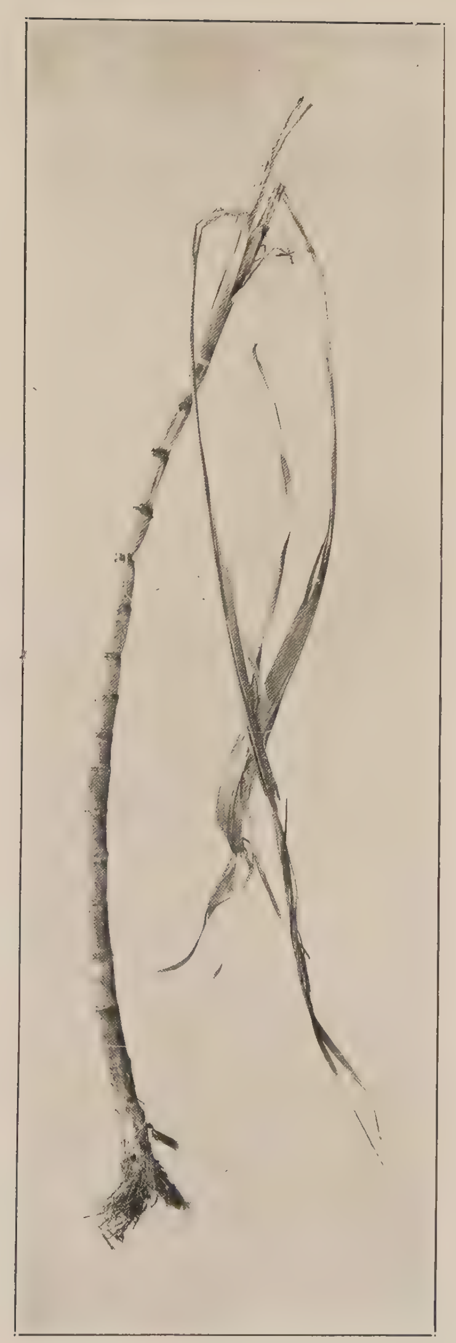


Fig. 4. Cane stick with shredded top. This stick was suffering from top-rot. Note the shrunken internodes.

"We have records of cases of top-rot in which the disease spread over considerable areas, and other cases where the affected cane was in small spots similar to those recently found at Honomu. The whole question of top-rot disease is somewhat confusing, since we know so little of its cause, the history of individual outbreaks being rather conflicting. A continuous study is not possible, owing to the lack of material for observation except at rare intervals and then only for a short period.

"In the recent outbreak in small spots at Honomu, Laupahoehoe, Olaa, etc., considerable evidence was obtained to support the theory that the tops of the cane were injured by some external factor and that the rot was but the natural decomposition of the dead tops. Lightning is a plausible factor which could account for this injury in circular areas and with the graduated relative amounts of injury from the center of the patch to the periphery, the taller plants being in general most affected, while leaves lower down escaped. Conceivably if the cane was struck by lightning when the leaves were wet, the effect would diffuse over the wet and exposed leaves (tallest plants, leaf tips, etc.) until the charge was so diffused as to be harmless. The charge might be insufficient to travel down the dry stalks and tear them out, thus leaving tangible evidence of the cause of the disturbance.

"In some similar cases of top-rot from Kauai, a hole in the ground several inches in diameter was noticed near the center of the spots, and soil deposited in the leaf bases was remarked. If lightning strikes cane, and we have no doubt it does occasionally, it is reasonable to believe that in some cases the charge is stronger than in others; the conditions as to electrical conductivity are variable, and thus the effect is diverse.

"In the material at Honomu most of the described symptoms of infectious top-rot were present, yet since it did not spread, we must assume that the conditions favorable to infectious top-rot were not long prevailing, or the cases in question were not infectious in nature, but rather rotting of the tops as a result of death from some undetermined cause. Where the cane is very dry and a sudden shower wets the top leaves, followed by lightning discharge, it likewise seems possible to the writer that the effect might be so diffused over the tops as to lead to the assumption later that the effect (disease) was spreading."

On February 5, 1921, further specimens of top-rot were received from the Hilo Sugar Company. The lower portion of the top-rot stalk received had a distinct cooked appearance. Late in March, 1921, our attention was called to three top-rot spots of cane at Ewa Plantation by Mr. W. P. Alexander. The cane is H 109, second ratoons, nine months old. On February 18 there was a severe electrical storm, the rainfall during several hours having been 1.2 inches at the mill. The diseased spots were not found until the irrigation gang made the next round.

These spots were not far apart, the first being about forty feet in diameter and the other two much smaller. In the larger spot there are about forty sticks showing top-rot, in the immediate vicinity of a stool one stick of which shows the top leaves shredded and the lower leaves and sheaths stripped neatly (Fig. 1). In another area the bolt shredded the top of one stick, and apparently jumped to an adjacent curved stick, as the leaves were stripped only part way down, and the adjacent stick had a rot lesion about 4 inches long on the side nearest the first mentioned stick. The first stick was stripped down to the point of departure, while the second stick was still healthy looking at the top but was stripped below the lesion. (Figs. 2 and 3.)

It would be purely fortuitous to observe lightning striking in cane fields and to definitely locate the spots where it hit. The fact that top-rot, in the experience of Cobb and others in Hawaii, follows rainy weather is possibly susceptible of deductions other than that wet weather favors the disease, as has generally been assumed. It is hoped that this note on top-rot and lightning injury will serve as a nucleus around which to gather additional data.

The Fig Wasp in Its Relation to the Development of Fertile Seed in the Moreton Bay Fig.

By C. E. Pemberton.

Summary.

The presence of the fig wasp is necessary for the natural development of the Moreton Bay fig and for the development of seeds as the sequence of the development of the male and female flowers in the fig prevents self pollination, and unless the female flowers are pollinated when the figs are young the figs fall off so that the male flowers do not come to maturity.

In connection with the propagation of the Australian fig, *Ficus macrophylla,* for reforestation purposes in the Hawaiian Islands, a study has been undertaken in Australia of the factors essential to the production of fertile seed of this tree. The following will cover the results of this work, indicating the vital part played by a certain insect in the perpetuity of the tree, showing in some detail its remarkable habits, and establishing proof of the absolute need for the introduction of this particular insect into Hawaii, before the tree can be permanently added to the forests and increase naturally in the future.

The most eminent botanists of modern times fully recognize the important part played by insects in the reproduction of many plants. The assertion of Eisen, an authority on fig culture, that "Nearly every flower we see in the field, and certainly every bright-colored flower, requires the visit of some insect, in order that its stigma may be fertilized by the pollen, which adhered to the insect, when it left the last flower visited," is amply confirmed by much elaborate work on insects in their relation to flower-pollination, by such prominent scientists as Kölreuther, Sprengel, Knight, Darwin, Hildebrand, Asa Gray, Fritz Müller, Hermann Müller, Trelease, Henslow, Knuth, Delpino, and a long list of others, totalling over 3,000 works relating to the subject. The fact is well established that no plants with colored or showy flowers existed before insects first appeared on the earth, and the development of their flower-parts following the occurrence of insects, has been very remarkable in the arrangments to prevent self-pollination and to attract insects to ensure cross-pollination.

Apart from the grasses, conifers, and many other plants completely lacking in colored, odorous or attractive flowers, the great bulk of the other plants now rely absolutely upon certain insects for the continuance of their virility or actual existence, through the cross-pollinating work of such insects. Plants of the genus *Ficus* (all species of figs) are included in this group. Their special flower adaptations directed to prevent self-fertilization and aid certain insects in fulfilling their mission of cross-pollination for the figs are most extraordinary.

Entomologists and botanists have long recognized the presence of certain peculiar wasps in figs of various sorts and much speculation has followed re-

Avenue of Moreton Bay figs (*Ficus macrophylla*) in the Domain, Sydney.

garding their importance to the fig in its development and in the production of fertile seed. As an example of their early recognition, Sir J. D. Hooker, as early as 1890, in the "Flora of British India," in an introductory discussion of the genus *Ficus,* states that "The gall-flowers are like the female but perfect no seed, their style is short, often dilated above, and the ovary occupied by the pupa of a Hymenopterous insect." This statement holds perfectly true to-day.

The Smyrna fig of commerce, grown extensively in Syria and Asia Minor, will develop to edibility only through the agency of one of these wasps. This fact has been known for hundreds of years. A simple horticultural operation designed to keep an abundance of these wasps present in the orchards where the Smyrna fig is grown has proven absolutely necessary, otherwise the crop fails. This process has been carried out in Greece since very ancient times. Aristotle left written accounts of the wasp and its importance. Theophrastus wrote extensively on the subject, with a fair understanding, and the elder Pliny, the great Roman naturalist of centuries ago, left important records on the knowledge the ancients had of it. Linnaeus, in 1749, wrote a careful account of the wasp and its habits. Smyrna fig trees were first imported into California in 1880 and extensively planted out. Though the trees grew well no figs were secured after many years of futile effort. Ultimately, through the co-operation of United States entomologists, living fig-wasps from Asia Minor, of the species particularly occurring in the Smyrna fig and its related, wild, so-called Caprifig, were imported into California and established in a Smyrna fig orchard of a prominent California fruit grower. Caprifigs were also growing in his orchard. In 1900 the first crop was picked. Sixty tons of splendid Smyrna-figs were taken from this orchard, and this was only after the thorough establishment of the wasp. Not a single fig matured during the many years prior to the introduction of the insect.

In a propagation of the Moreton Bay fig in Hawaii, the experience will be necessarily similar to that in California with the Smyrna fig. It can develop fruit and reproduce only through the aid of its own particular fig-wasp, which occurs in the figs of this tree in certain parts of Australia, and it is absolutely essential that this wasp be established in Moreton Bay fig trees in Hawaii before they will ever produce fertile seed. The following account should be sufficient to prove this point.

Three main types of flowers occur in figs. These are the male, female, and gall flowers. Flowers known as neuter are also said occasionally to occur. Each receptacle or fig bears on its inner wall great numbers of these flowers. Some species of *Ficus* bear figs on one tree in which only male and gall flowers are present, and on another tree, figs containing only female or seed-forming flowers. In other species both male and female flowers occur on the same tree but in separate figs; the gall flowers always occurring in the same fig with the male flowers. Still other species of *Ficus* bear all three kinds of flowers in every fig produced. The Moreton Bay fig is of the latter type. Here (Figure 1) each fig contains an abundance of male or pollen-bearing flowers, true pistillate or female flowers in which the seed develops, and certain imperfect female flow-

Ficus macrophylla in the Botanic Garden, Sydney.

ers known as gall flowers which exist and function solely to hold and nourish the developing fig-wasps.

In Figure 2 a much enlarged view is shown of the three kinds of flowers present in every immature Moreton Bay fig. The perianth of each has been removed to show the relative size and shape of each, all being drawn to the same scale. The flowers have this appearance when the fig is small and the basal bracts surrounding it are just unfolding, as shown in Figures 3, 4, and 5. The fig is then about one-half inch in diameter, with considerable variation and is somewhat hollow. When a fig-wasp enters, there is plenty of room for it to move about freely in order to lay its eggs. All three types of flowers are well distributed. The male flowers are not confined to any particular part of the fig as in many other species of *Ficus*.

Figure 2A shows the normal female flowers, destined to form a fertile seed. At this time, while the fig is small and young and the basal bracts shown in Figures 4, 5, and 6 are just opening, the stigma of this flower is widely expanded, pale white in color, erect and fully ready to receive any pollen which may get on to it from a fig-wasp when it comes into the fruit to lay its eggs. A few weeks later this stigma withers, the style supporting it droops, both assume a dead, brownish color and any pollen then reaching the stigma is powerless to effect a fertilization of the ovary. Figure 8 shows the appearance of the same flower, after being properly pollinated and matured to a perfect seed. Figure 2B shows the gall-flower as it normally appears in a young fig, mixed in with the other flowers. There are a hundred or more of these in each fig. In this type of flower and in no other, the fig-wasp lays its eggs as explained below. This flower, though a pistillate or female one, is destined to produce a fig-wasp and not a seed, if an egg is deposited into it at the proper time. The stigma appears quite similar to that of the true female flower both as to size and shape and in the apparent possession of well-developed receptive glands. The style, however, is normally shorter than that of the female flower, as shown in the figures. There is considerable variation in this. Gall-flowers have been found with fairly long styles. The short style of the gall-flower enables the female wasp to place its egg properly within the ovary below. The male flowers, in which the pollen develops, shown in Figure 2C, are very immature in any given fig, at the time the female flowers in the same fig (Figure 2A) are just ready to receive the pollen. The female flower, as just explained, is ready for the pollen and must have it then or never. This is when the fig is small and the basal bracts are just opening. All of the male flowers in it then are very immature and will not dehisce or rupture and scatter pollen until the fig is ripe, several weeks later. Hence the need for some agency to bring ripe pollen into this tightly sealed-up, undeveloped fig, from some ripe fig on the same or another similar tree. Here the fig-wasp plays its part.

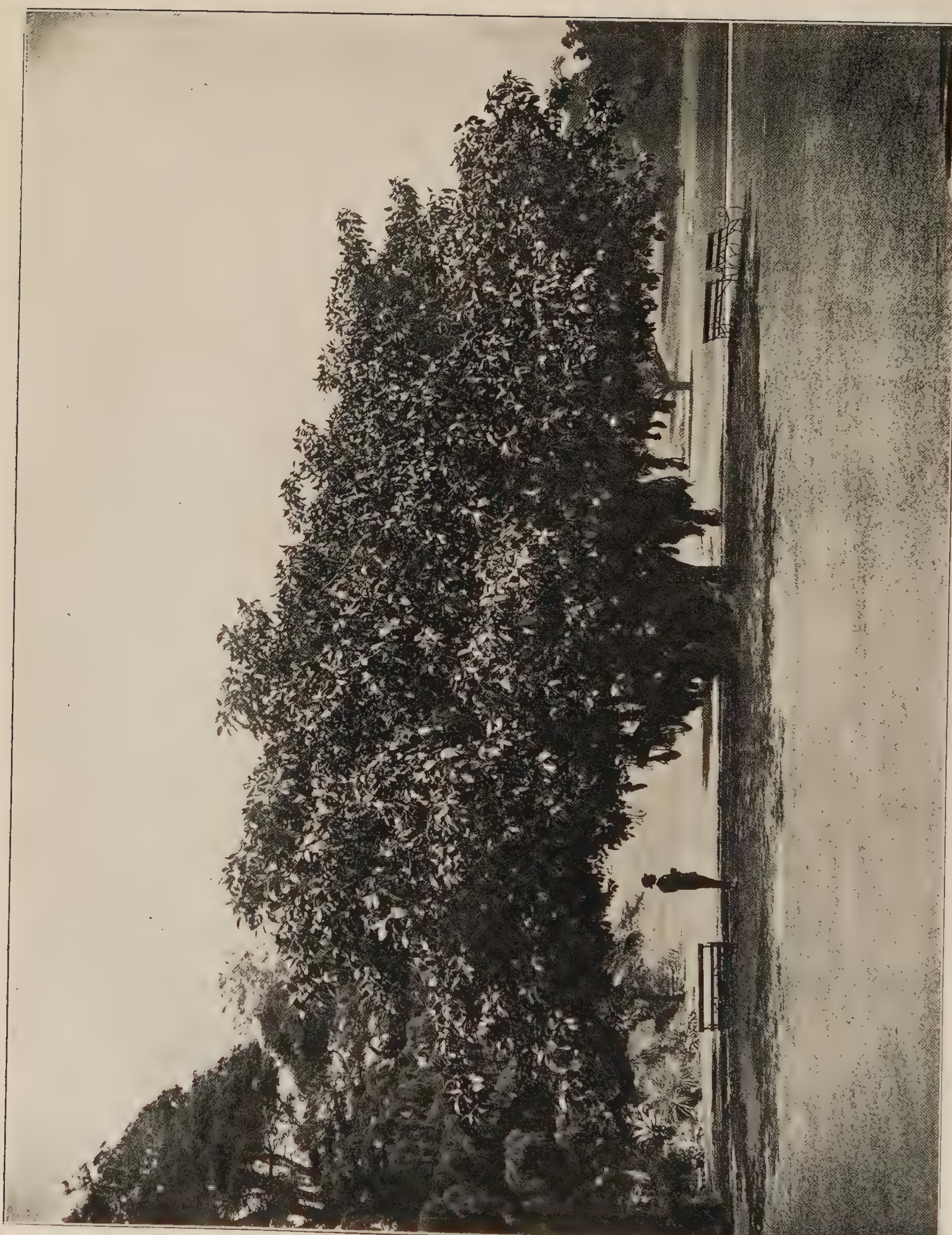
Though fig-wasps of several species are present in the Botanic Gardens in Sydney, Australia, where the present investigations were carried out, only one species, *Pleistodontes froggatti* Mayr, was bred from the Moreton Bay fig. Mr. W. W. Froggatt records another species, *P. imperialis* Saund., though it is apparently rare.

Ficus macrophylla in the Botanic Garden, Sydney.

The common *Pleistodontes* commence boring out of mature figs, as shown in Figure 7, about a week before the fruit falls to the ground, with variations depending upon wind, rain, and temperature. The figs, which are light green in color, are just beginning to soften, assuming a yellowish tinge, when the wasps emerge. They then quickly change to red, purple, and finally dark purple, become very soft and fall to the ground. Only the female wasps leave the figs. They easily emerge by boring minute holes through the wall of the fig at any convenient place. See Figure 7. When from one to six holes have usually been made, through the emergence of a similar number of females, the others hatching within the fig seek an outlet through these holes. Hence only about one to six perforations appear on a fig after the females have hatched out and these suffice for the liberation of often eighty or ninety wasps. On December 17–18, 1920, a total of ninety-three females emerged from a single fig under observation. At just the particular time when the wasps are hatching from the fig, the male flowers in the same fruit are reaching maturity, the anthers or pollen sacs are rupturing freely, by a single, longitudinal slit, and a vast quantity of minute, white pollen grains are scattered throughout the interior. It is remarkable that the pollen should thus be naturally liberated within the fig at just the time the wasps are hatching out. This, however, is invariably the case. Every wasp becomes covered with pollen, without exception. Some emerge literally white with it.

The female will fly readily. Her immediate aim upon leaving the fig and partially cleansing herself of excess pollen, is to locate a small fig with the enveloping bracts just opening to expose the tip. She quickly flies up and away. She is capable of an extended flight, through the help of the wind. She may be carried a long distance from the tree from which she hatched. Individual females have frequently been taken, very much alive, on the roof of a hotel in Sydney, well removed from the Botanic Gardens or any fig trees.

Instinctively a fig of the proper size is soon found and the female commences an elaborate operation of boring into it at its apex or end, just where a series of eight to twelve imbricated, elongate, turned-in scales close the end. A female never attempts to enter a fig at any place but this. The area of operation is very small, hardly exceeding more than a sixteenth of an inch in diameter. If the bracts covering the fig have not opened sufficiently to expose this spot, as shown in Figure 6, the wasps can frequently be seen moving about over the fig near the apex, apparently awaiting the unfolding of this leaf-like fig-covering. As soon as the tip of the fig is exposed, one or more wasps usually find it and commence boring in. As many as fifteen females have been counted, all trying to insert their heads into the fig at exactly the same spot. Many never enter, are crowded out by the others, and only get the head partially imbedded. Most young figs thus soon have one or more dead wasps at the tip, with the bodies projecting from the fig and firmly held by the head, which is wedged in a fraction of an inch. From one to six, or sometimes more, usually gain entrance, however, into most of the young figs. A wasp will not enter such a fig if a hole has been previously made for it at the apex. A fine needle-hole made at the exact spot desired by the wasp for entrance was several times



Ficus macrophylla in the Botanic Garden, Sydney.

made in young figs, and large numbers of freshly-hatched females then placed on the fig. None were ever seen to enter this hole. They began gnawing around the edges. The instinct to enter by force, only after a laborious and often fatal effort, through the sticky, tough, fig-skin, is apparently as much a part of the necessary life-function of this wasp as that of laying eggs. No food seems to be taken while boring into the fruit. The alimentary canal of several has been carefully examined just after the individuals had passed into the fig. Nothing could be found but the minute, spherical masses of oil-like globules which are present in newly-hatched females taken before entrance into a fig.

The structure of the head of the female is remarkably adapted for facilitating the difficult entrance into a fig. At the time the wasp works into it, the wall of the fig is comparatively strong and hard. The tissues are full of the thick, milky sap which flows at the slightest scratch. The entire process of gaining entrance is a slow one, though the actual distance through which the insect cuts is hardly greater than the length of its head. As above stated, many never succeed in entering and die in the attempt. This sometimes occurs even when there is no crowding about the fig-apex. Several individuals have been kept under observation from the time they commenced boring into the fig until the tip of the body and the posterior pair of legs had finally disappeared. The time required in these cases varied from one hour and twenty-five minutes to one hour and forty minutes. The wasp first moves about over the end of the fig, attracted probably to the desired spot by a sense of smell. She finally applies the tip of the head against the fig and becomes perfectly motionless. The two first antennal segments are brought close together, are somewhat pointed and project slightly in front of the tip of the head, just beyond the mandibles. These are pressed against the fig, the other joints extending upwards and in front of the head. The two strong, hook-like mandibles are then raised and lowered slowly. They do not operate laterally. The motion is more forward and backward. In raising them the tips are pushed forward. In lowering them, they are forced against the tissue. This can be better understood after an examination of Figures 12, 13, 14, and 15. It is somewhat of a forward-reaching movement to fix the tips into the tissue in front. Then in lowering them the whole body is drawn forward an imperceptible distance. The remarkable so-called "mandibular appendages," attached to the bases of the mandibles and extending ventrally backwards the length of the head, are so beautifully constructed and situated that each movement of the mandibles forward draws the appendages forward also, and the saw-like serrations and spines with which they are totally covered, as shown in Figures 12, 13, 14, and 15, completely prevent the head from slipping back. Every forward movement of the head, gained by ever-so-slight a penetration by the mandibles, is insured against slipping back by these barb-like appendages. As the wasp slowly gains further entrance into the fig, the appendages may be expanded laterally, as shown in Figure 13, which doubly prevents any but a forward movement of the wasp, once it inserts its head slightly into the fig. When first establishing a hold on the surface of the fig the wasp will revolve its body to the right and left with the tip of the head pressed against the fruit and acting as a pivot. The movement is always slow.

After a third or more of the head is into the fig tissue, the entire body becomes raised from the fig and the only portion in contact is that part of the head inserted. The legs and wings then extend backwards in a rigid manner, as shown in Figure 4, remaining almost motionless and utterly useless. As the action of the mandibles and their appendages draws the body further in, the legs are brought into use and are the sole means of pushing the body completely through the aperture after the head has passed entirely into the open interior of the fig. Specially developed claws or spines on the anterior and posterior pairs of legs are present to assist in this operation.

The difficulties encountered by the wasp in piercing the fig-wall invariably result in the loss of the wings and the outer six antennal segments. See Figures 16 and 17. Many hundreds of females have been examined after penetrating into the fig, and the wings and six antennal segments are always missing. The wings usually remain protruding from the end of the fig, glued there by the small amount of sap exuding from the wound made in the fruit where the wasp entered. The broken-off antennal segments are less conspicuous, but can be found in the fig-wall near or at the outer surface just where the wasp entered. No cases have been observed in which the wasp lost any legs or portions thereof in entering a fig. When the wasp is finally into the fruit she resembles that shown in Figure 6, greatly enlarged. Usually more than one wasp gets into each young fig, and often five or six will successfully enter a single fruit. After a few wasps have thus entered, either fresh wasps are unable or have no desire to enter this particular fruit, for no fig has yet been opened in which more wasps had entered than could conveniently move about in the small interior for egg-laying. Yet there are generally more wasps about a tree than are necessary for the proper fertilization of all the figs thereon. Much of the pollen must be brushed from the wasp's body during the short but strenuous trip from the soft, mature fig from which it hatched to the interior of the solid, sticky, milky, young fig, where it has finally arrived to lay its eggs. Many have been removed after reaching the center of a young fig and their bodies carefully examined for pollen grains. Though usually found on some part of the wasp's body, it must be admitted that pollen grains are not frequently numerous; yet sufficient is carried over to secure ample pollination for a great many female flowers in each fig.

When a female has finally reached the interior of a fig, she immediately begins egg-laying. She very energetically searches about over the surface of the flowers with the ovipositor withdrawn from the sheath, forcing the tip into every stigma encountered with the evident intention of finding the stigma of a gall-flower. There is only a moment's pause over each stigma until the desired one is found. Then the ovipositor-blades are run through the stigma, down along the channel of the short style and well into the ovary itself, not in the center, but to one side. The blades are then held in this position while a minute egg, hardly one seventy-fifth of an inch in length, with one end attenuated to a long, drawn-out stalk, passes down between them and is deposited into the base of the flower. The freshly laid egg is shown in Figure 11, very greatly enlarged. The position of the female while ovipositing is shown in Figure 6

and the egg in position is seen in Figure 18. Many ovipositing females have been removed from figs with the flower intact, placed beneath a microscope and observed during the operation. Even under this disturbance the wasp will continue working until the egg has been laid. Under strong lighting, the ovipositor can be seen in position within the tissues of the delicate, transparent gall-flower. Several minutes are usually required to deposit a single egg. Some have been timed for five minutes before the ovipositor was withdrawn. The female continues laying in gall-flowers until death. Her egg-laying capacity is fairly large. The greatest number of well-developed eggs dissected from a single newly hatched female was 149. As her life is very short, the eggs seem all nearly mature when she first hatches out. A single individual is thus capable of placing an egg in nearly every gall-flower in a fig. Sometimes, after ovipositing her eggs, a female attempts to bore out of the side of a fig. She never succeeds in this. Many have been found dead with the head partially imbedded in the inner wall of the fig, but a complete emergence hole has never been seen on a young fig. Females usually remain alive and continue egg-laying in a fig for about two days after first boring in. Sixty-eight individuals were placed upon screened-in, young, untouched figs on December 24th, 26th, and 28th, 1920. Six were still living and trying to oviposit when the figs were opened forty-eight hours later, but they were feeble. All the others had died. The life of an adult is thus very short under normal conditions. Many attempts were made to prolong the life of the adults beyond a few days. None could be made to take sugar and water or honey and water and thus kept alive for long periods, as can easily be done with many Hymenoptera. The longest life of any individual kept under experiment was four days. Of a total of 200 freshly emerged females placed in test-tubes and kept in absolute darkness, twenty-two lived for three days and five held out for four days. Other lots placed in the light and fed various substances all died after two days. As shown below, their life can be best prolonged by subjection to fairly cold temperatures. Most probably, as experienced by Back and Pemberton in fruit-fly refrigeration experiments, the nearer 50° or 51° F. they can be held, the longer their life can be prolonged. Future shipments of different species of fig-wasps from different countries in connection with the propagation of various trees of the genus *Ficus,* will probably find greatest success in the adoption of such a method where it is impracticable to ship the living tree with the wasp.

The fig continues growing rapidly after the wasps have entered it, laid their eggs, died therein, and incidentally brought in the pollen for the female flowers. The interior space wherein the wasps moved about, soon becomes completely filled with the enlarging flowers, of all three types, and the dead wasps become greatly crushed, distorted, and partially dissolved by the thick sap in the fig.

The egg, within the gall-flower, hatches into a small, pale-white, and exceedingly delicate larva, wholly devoid of any striking or readily recognizable characters. The mandibles are only faintly chitinized and not easily found. The length of the egg-stage was not determined. The larva remains within the gall-flower, feeding upon the surrounding tissues, and the flower itself grows

Ficus henneana in the Botanic Garden, Sydney.

to more than double its original size, finally assuming the shape shown in Figures 9 and 10, with some variations. The larva matures within the gall-flower and pupates therein. Both male and female pupae have been dissected in quantity from the gall-flowers.

The males hatch out first by gnawing, with strong mandibles, a small hole in the top or side of the gall-flower, creep out and immediately work slowly and clumsily about in the fig searching for other gall-flowers in which female wasps are maturing. The male is wingless, yellowish-brown in color and quite unlike the female in general appearance. It is of the same peculiar type as that of the male of the Smyrna fig-wasp and many described from other figs. The male outlives the female by several days and is much less numerous. When a gall-flower containing a female is found, the male gnaws a hole, usually in the side of the gall, inserts the tip of the abdomen, fertilizes her and then moves away to another flower. The female then works her head through this hole, enlarging it somewhat, as shown in Figures 9 and 10, and emerging into the interior of the fig; then boring immediately through the side at any point or seeking an outlet through some emergence-hole just bored by another escaping female, and thus completely leaving the fig. At this particular time, as previously indicated, the male flowers in the fig have ripened, ruptured, and cast a profusion of pollen throughout the inside. It is thus impossible for the female to escape without being covered with pollen, and she immediately starts in search of young figs, as discussed above.

The time required for the total development of the wasp is necessarily dependent upon temperature and the growth of the fig. The wasp-maturation is completely coincident with the development of the fig. At a season when the fig requires three months for formation and full ripening, the wasp does not emerge from the fig until that time. It cannot do otherwise, for it never leaves the fruit until it has ripened and softened, and it always enters it when it is in a certain immature condition. When a winter season prolongs the development of the fig, the growth and maturity of the wasp must also be prolonged.

The details above show how absolutely impossible it is that pollen could ever reach a female flower at the time it requires it without this wasp hatching from a ripe fig in which pollen has just been scattered, leaving the fruit with its body covered with the pollen and immediately flying to, and boring into, a young fig containing female flowers just ready for the pollen that the wasp has unintentionally brought with it. The wasp must enter the young fig to lay its eggs in certain gall-flowers at a particular time, otherwise those flowers will have withered and will be unsuitable for the wasp, and the true female flowers, destined for seed, must have pollen at just this time, otherwise they wither and dry up and never form seed. Hence the remarkable coordination in the development of both seed and wasp. The wasp is absolutely dependent upon this particular fig-species to perpetuate its kind, and the tree is equally and totally unable to continue existence without the ceaseless aid of this particular wasp. A tree might be planted and grow for one hundred years or more, but without the presence of this wasp there would never be any fertile seed formed in its figs, and it would ultimately perish with none to take its place.

Fig trees native to Fiji were studied during 1920 and found to be equally dependent upon particular wasps in each case.

Several species of Hymenoptera other than *Pleistodontes froggatti* were bred from the fruits of the Moreton Bay fig. None are true pollinators nor do they play any part in the development of the fig. They never bore into the young figs. All deposit their eggs into the fig-flowers by forcing the ovipositor through the fig-wall from the outside. Their larvae can serve only as parasites of the true fig-wasp, parasites of one another, or as simple plant feeders within the fig-flowers. All, so far examined, develop wholly within the fig-flowers and not on the fig-pulp. They have been excluded in the introduction of the true fig-wasp into Hawaii.

Mr. W. W. Froggatt, Government Entomologist of New South Wales, was the first to present an account of fig-wasps in the fruits of *Ficus macrophylla*. This appeared in the Agricultural Gazette of New South Wales for June, 1900. This interesting paper offered much of interest regarding the habits of *Pleistodontes froggatti* and other insects associated with it in the figs, and has been very useful for reference in connection with the details included in the present paper. In Froggatt's "Australian Insects" appears an excellent plate showing various views of the same fig-insects, illustrating some of their habits.

The most complete recent work on the habits of fig-wasps was published in the Philippine Journal of Science, Section D, April, 1913, by Mr. C. F. Baker, under the title, "A Study of Caprification in *Ficus nota*." Many of the details herein presented on the habits of *Pleistodontes froggatti* were identically observed by Mr. Baker in respect to the life-history of the particular wasp developing in and fertilizing the seed of *Ficus nota*.

Cunningham, in 1889, in the Annals of the Royal Botanical Garden, Calcutta, (Vol. I, Appendix), describes the flowers of *Ficus Roxburghii* and the effects of the presence of insects upon them. From his studies he concluded that it is not pollination that causes the developments, but the irritation caused by the act of oviposition. This species of fig is dioecious, one tree producing figs containing male and gall flowers and another tree bearing figs containing true female flowers capable of producing seeds. That the Smyrna figs can be pollinated artificially and develop mature fruit without the presence of insects has been demonstrated by Roeding in California. Similar tests should be made on *Ficus Roxburghii* before Cunningham's conclusions can be accepted.

The Moreton Bay fig is grown artificially in regions where the wasp herein discussed is not present, and in all such places no fertile seed is ever formed. In the Botanic Gardens and the Domain in the City of Melbourne, Australia, large, beautiful avenues of this tree have been planted. Fruits form in abundance, but no fertile seed has ever been formed here, according to Mr. Cronin, the Director of the Gardens. An examination of these trees was made to determine the cause for this, if possible. No *Pleistodontes* or fig-wasps of any species were found in the trees. A thousand figs were collected and each carefully examined. No seed development could be noted in any and no wasps in any stage were present. The pulp and seeds do not develop to any size and the fruits always fall to the ground in a hard, immature condition. The absence

Ficus eugenioides in the Domain, Sydney.

of the wasp easily explains this. Possibly the winters are too cold in Melbourne for the few wasps that may accidentally reach there occasionally from Sydney or the regions to the north. It seems more probable, however, that none have ever reached the region at a proper time or in a proper condition.

Large trees of the Moreton Bay fig were also found growing abundantly in Auckland, New Zealand. No figs ever mature there, no fertile seed is ever formed and a careful examination of much of the fruit on the trees soon showed that no fig-wasps were present. The tree has simply been introduced from Australia without the necessary wasp associated with it. Several splendid Moreton Bay fig trees were also found growing at Lautoka, Fiji. Examination of a large quantity of fruits from these trees also indicated the absence of the *Pleistodontes* wasp and of fertile seeds. Many other fig-wasps are present in Fiji, living in the native figs, but will not of course take to any but their own particular species of *Ficus*. The two mature Moreton Bay fig trees growing in Honolulu form no fertile seed and the fig-wasp has never occurred in them. These have been under the observation of Dr. H. L. Lyon.

Occasionally, when the succession of fruits among the Moreton Bay fig trees in Sydney is such that few figs are ripening near some tree on which most of the young fruits are just appearing, many of these young figs will become too old for proper fertilization before wasps reach them with pollen from some other tree. Hence these fruits fall to the ground prematurely, just as among the trees in New Zealand, Fiji, Honolulu, and Melbourne, and contain no fertile seed. One such tree was found in Sydney on January 5th, 1921, rather distant from any other fig trees and bearing a quantity of young fruits, most of which had not been reached soon enough, or at all, by fig-wasps. These fruits had accumulated on the ground in great numbers. Fifty-one of them were gathered from the ground and examined. None contained fig-wasps, which readily explained why they had fallen. Twenty-six fruits of better size that were still growing on the tree were then examined and each was found to contain from one to five fig-wasps. They had many days before entered these figs, carried the pollen in, laid their eggs, thus establishing proper conditions for the maturity of the fruit, and then died. Here it is quite evident that the isolation of the tree had permitted only a moderate number of wasps to reach it and bring about the fertilization of only some of its fruits. The remainder failed to mature in the absence of fertilization and fell to the ground prematurely, just as though there had been no wasps in the community.

On some trees figs were enclosed in a gauze bag when very young to prevent wasps reaching them at the proper time. None of these ever matured or developed fertile seed.

There is a constant succession of fruiting among most of the trees in Sydney, which have been under observation for several months, during a study of the wasp. Some trees will be just forming fruits, while the figs on others will be mostly ripe, or on some may be only one-half developed. There appears, however, to be somewhat of a seasonal development, the majority fruiting together. The ripe fruits were found to be much more numerous in Sydney in March than in December or January. Yet the variation in the fruiting of each

tree throughout the year provides a sufficiency of ripe and young fruits at all times to provide a suitable condition for the fig-wasp. Newly hatched females can thus nearly always find some young figs just right for the reception of their eggs.

It is interesting to note here that of the many species of imported figs growing in the Botanic Gardens in Sydney, none ever produce fertile seed, with one exception, and none have had their particular fig-wasps introduced with them. The exception is the Lord Howe Island fig, *Ficus columnaris*. It has been planted in the Gardens in Sydney. When it became old enough to form fruits, the *Pleistodontes* wasp of the Moreton Bay fig took to it and successfully bred in it, thus establishing pollination in its flowers and causing normal seed development. A large number of *Pleistodontes froggatti* have been bred from its fruits. It is, according to Mr. Maiden, botanically close to *Ficus macrophylla*. The fruits and flowers are almost identical. A quantity of seed of this tree was collected and sent to Honolulu in January, 1921.

Cunningham stated that *Ficus Roxburghii* in the Botanical Gardens of Calcutta is not attended by its native insect of Sikkim, but he did not state the local host of the insect he worked with in Calcutta.

On January 27th, 1921, several hundred well-grown figs from the Moreton Bay fig tree were collected in Sydney for shipment to Honolulu, with the fig-wasp contained within them. The fruits were just reaching maturity; some were still fairly hard and others were just commencing to turn yellow and soften. These all contained large numbers of living *Pleistodontes* pupae, many of which were about to hatch. The lot was divided in half. One portion was inserted in a cloth-lined shipping case, filled with trays to hold the figs apart. This was placed on the upper deck of the steamship "Ventura." The other portion was placed in a cardboard box, each fig being wrapped separately in paper and the box then tied securely in a canvas bag. The bag was then placed in a refrigerating room, aboard the same steamer, in which a temperature of about 45° F. was constantly maintained. About two weeks later the material reached Honolulu. All wasps in the figs on deck were dead, while the cold-storage lot arrived in good condition and 2000 living females were liberated in the two Moreton Bay fig trees then in Honolulu. Females were soon observed to enter young figs. This should thus ensure their establishment in Hawaii for use in years to come when the quantity of seed which has been collected in Sydney, in connection with the present study of this insect, has been germinated in nurseries, set out in the forests, and finally matured to fruiting trees.

Attached herewith are photographs of Moreton Bay fig trees as they appear in the Botanic Gardens and Domain in Sydney. They indicate the splendid proportions to which the tree grows and the great depth of shade cast. These trees are all growing in a very shallow soil, covering a stratum of solid sandstone. The tree is generally recognized as capable of withstanding very adverse conditions. Mr. J. H. Maiden, Government Botanist and Director of the Botanic Gardens in Sydney, states in the Agricultural Gazette of New South Wales for October, 1908, that "It will grow amongst rocks where scarcely anything else will grow, and it will stand being blown upon by fierce winds and

EXPLANATION OF FIGURES.

Figure 1.—Ripe Moreton Bay fig, cross-section, showing mature female flowers (Seeds), gall-flowers from which fig-wasps have hatched, and ruptured pollen sacs or male flowers. About natural size.

Figure 2.—(A) Young female flower just ready for reception of pollen. (B) Young gall-flower at proper age to receive egg of fig-wasp. (C) Immature male flower in the same young fig with (A) and (B). All drawn to the same scale. Enlarged about twenty times. *ps.*, pollen sacs; *stig.*, stigma; *sty.*, style; *ov.*, ovaries.

Figure 3.—Very young fig, showing bracts still enclosing the fig and covering the apex and thus preventing the wasp from entering. The flowers within the fig are not ready for pollen carried by the wasp or for the wasp's eggs until these bracts have just opened, as in Figures 4 and 5. Wasp awaiting opening of bracts. All enlarged about one and one-half times. *b.*, bract.

Figure 4.—Young fig, showing characteristic position of female fig-wasp boring into the apex. The body projects in midair, as shown, as soon as the head becomes well imbedded. Enlarged about four times.

Figure 5.—Young fig, showing usual position of female fig-wasp after head has penetrated well into the fruit. The legs from here on assist in the entrance and the wings are about to be broken off. Enlarged about two and one-half times.

Figure 6.—Portion of inner wall of a young fig, showing female ovipositing into a gall-flower. This illustrates her characteristic egg-laying position. Note the absence of wings and antennal joints, and that she has selected a gall-flower in which to lay. Much enlarged.

Figure 7.—Fully developed fig, showing female wasps boring out of it. At this time the females are covered with pollen. About natural size.

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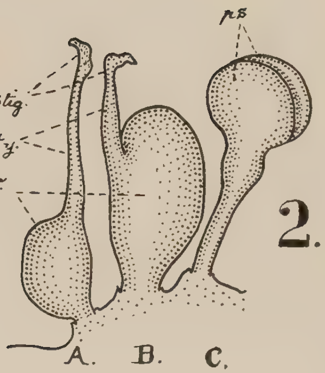

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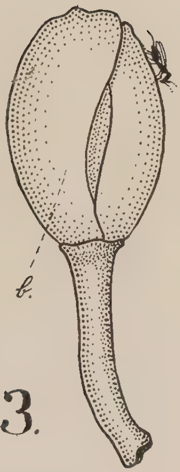

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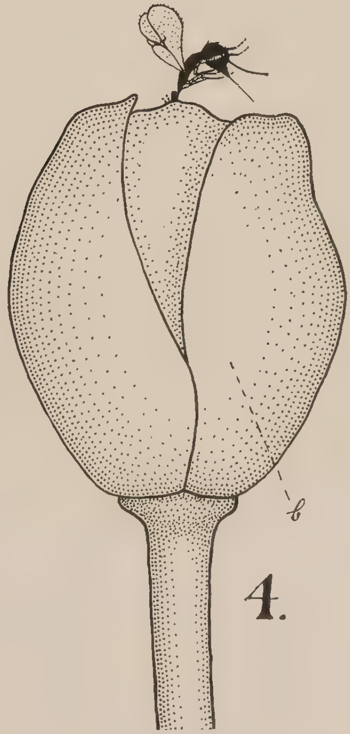

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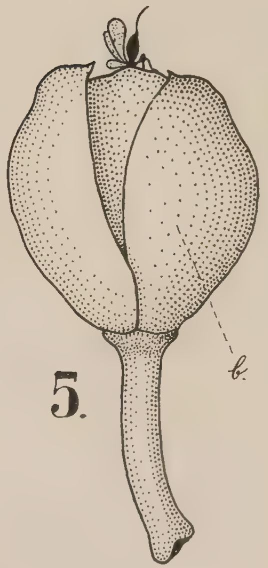

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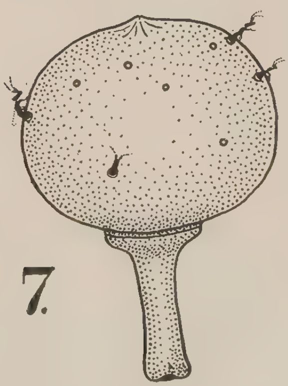

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Figure 8.—Mature female flower after having been properly pollinated. This, with some variations, is the general appearance of a fertile seed. Enlarged about fifteen times.

Figure 9.—Gall-flower of mature fig, from which a fig-wasp has emerged. Much enlarged.

Figure 10.—The same as Figure 9, but showing the female wasp just working her head out of the flower. Much enlarged.

Figure 11.—Egg of fig-wasp freshly laid. Enlarged about 490 times.

Figure 12.—Mandible of female, showing mandibular appendage. Very greatly enlarged. *M.*, mandible; *m. a.*, mandibular appendage.

Figure 13.—Head of female. Ventral view. Showing position to which the mandibular appendages may be extended during the peneration of the wasp into a young fig, thus preventing slipping back. Very greatly enlarged. *M.*, *m. a.*, same as in Figure 12.

Figure 14.—Head of female. Ventral view. Showing the two mandibles with their attached appendages. Very greatly enlarged. *M.*, *m. a.*, same as in Figure 12.

Figure 15.—Head of female wasp. Lateral view. Showing mandibles and mandibular appendage. Very greatly enlarged. *M.*, *m. a.*, same as in Figure 12.

Figure 16.—Normal female antenna just before entering a fig. The outer six joints are still intact. Very greatly enlarged.

Figure 17.—Showing all that remains of a female antenna after she has bored into a young fig. Very greatly enlarged.

Figure 18.—Young gall-flower, showing fig-wasp egg in position. Much enlarged.

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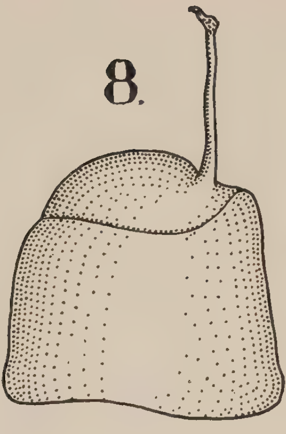

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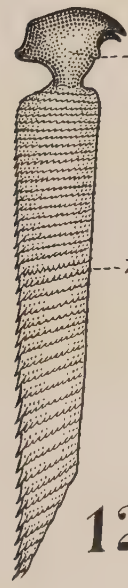

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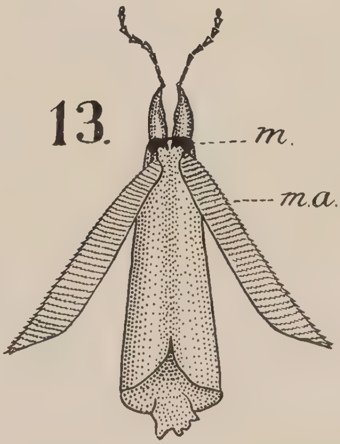

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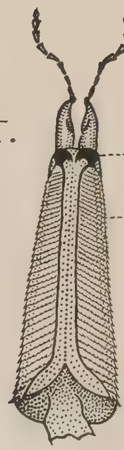

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being hacked about and otherwise ill-used. I admit that it can be put in the wrong place; but a Moreton Bay fig, with plenty of room so that it can live its life, is one of the most beautiful of trees, while its foliage and fruit are nutritious to stock, and its umbrageous head affords a grateful shade. I have drawn attention to the value of this tree to dairy farmers. The observations were original as regards Australia, though I afterwards found that leaves of other species of *Ficus* were used for feed in parts of India.

"Bearing in mind the way in which these and other native figs flourish exceedingly in the poorest soil, that cattle devour the leaves and branchlets greedily, that they will submit to persistent hacking back to an extent which will kill most other trees, it seems a matter for consideration that these trees should always be planted for shade purposes on dairy farms and they should even be planted as a reserve of fodder in stony, sterile places where no grass will grow."

Mr. J. S. Walford of Sydney has written of the Moreton Bay fig as follows: "I think I may with safety state that Moore Park (Sydney) will carry all the year round, good season and bad, as many horses as any equal acreage of the best of country. This statement is borne out by the mob of horses that may be seen any month of the year grazing in one or other of the paddocks; and it is only made possible by the Moreton Bay fig tree. The stock eats greedily the figs and fallen leaves. I have seen cows in the Domain leave grass which was fetlock high to eat ravenously the leaves on the lopped-off branches of the Moreton Bay fig trees.

"If the tree will grow inland, immense quantities of leaves and bark could be obtained in dry weather and the branches could be cut back to the bare stump, which would again grow luxuriant foliage by the time another drought occurred. How hard it is to kill a Moreton Bay fig tree may be judged from the fact that some years ago, when the row of trees was removed from Government House grounds, the roots were cut through and some of the stumps were carted to Moore Park and planted. These stumps struck and are now fine trees."

Mr. Maiden fully corroborates the above statements.

It is usually called a "dirty-tree" in Sydney, owing to the large quantity of leaves and fruit that constantly accumulates beneath it. As a forest tree this is an exceedingly desirable character. A deep, spongy mulch, with splendid water-holding capacity, is certain to form under these trees.

Mr. C. Hedley, of the Australian Museum, Sydney, states that in the vicinity of Moreton Bay, Queensland, where this fig is indigenous, it normally starts in a forest as an epiphyte. The fruit is eaten by birds and the seed dropped in the crotch of some tree. There it germinates, sending roots down along the surface of the limbs and trunk, finally reaching the ground, taking root, growing larger and larger, ultimately strangling the tree upon which it started, and thence continuing from a large vine to an enormous tree. It is possible, however, that the tree may occasionally start naturally from a seed which has germinated on the ground or in a rock-crevice. Seedlings have been found growing beneath large trees in Sydney, though scarce. They do not survive, however, under park conditions.

Photographs are also shown of other species of figs, possessing splendid forest qualities, which are now growing in the Botanic Gardens in Sydney. Seed of all has been collected and forwarded to Honolulu during January, February, and March, 1921, together with specimens, for future reference, of the particular fig-wasps associated with each.

NOTE.

The fig insects sent from Australia by Mr. Pemberton were liberated on February 9th. It is still too soon to be quite sure that they have failed to establish themselves, but up to the present we have found no mature figs on the trees where the insects were liberated. If a single fig in an upper branch of the tree came to maturity it would be enough to start a colony. If they have not established themselves it must be because the pollen they carried with them had not survived the two weeks' journey in the cool chamber.

F. M.

Boilers and Economizers.*

By Dr. D. S. Jacobus.

During the year 1920 the trend of boiler design has been toward the use of a greater number of tubes in height for a given class of work. Adding to the height of the boiler adds to its efficiency with a relatively small increase in draft resistance. By adding to the height of a boiler, leaving the lower part of it and the stoker and furnace the same, the efficiency is materially increased for a given amount of steam produced, the curve of efficiency at different ratings being both raised and flattened. Among large boilers recently installed are some which evaporate in the neighborhood of 150,000 pounds of water per hour under actual conditions, this size being a convenient one to use in connection with the largest steam turbines.

Boiler pressures are also being gradually increased, a number of installations having been installed in which the working pressure is 350 pounds with a superheat of from 200 to 225 degrees, and with some changes in design there seems to be no reason why higher pressures are not perfectly feasible; in fact, test boilers have been built for 500 pounds pressure and over.

The question is often raised as to whether it will pay to install economizers. Each case must be considered by itself. As the price of fuel increases, naturally the use of economizers will increase. In considering the use of economizers, the additional efficiency secured through adding to the boiler surface by increasing the height of the boiler should be taken into account. If we start with a boiler, say, 14 tubes high, adding tubes so as to make the boiler 16, 18

* Reprinted from "Power," January 4, 1921.

or 20 tubes high, will, for a given amount of fuel burned per hour, result in each case in added efficiency. This additional efficiency is secured without a very great increase in the draft loss, as much of the draft loss in boilers comes through the turns that the gases make over the baffles. The higher boilers can in most cases be operated with natural draft up to the desired capacity, whereas should economizers be installed an induced draft is ordinarily required. In some cases the simplification of the plant by using the higher boilers as compared with one having economizers warrants the use of the higher boilers.

To show how misconceptions respecting boiler performances arise, consider the case of a small plant having several boilers, one of which is uneconomical with a low draft resistance. The flue gas temperature for this unit will be higher at a given rating than for the others, and the amount of power obtainable from it will be higher than from the others. This would be especially noticeable if the uneconomical boiler was shut down, as there would then be no additional draft through the higher temperature of the gases from the uneconomical boiler. The operating crew would soon find that when the uneconomical boiler was cut out of service the capacity would fall off more than in cutting off any of the others, and they might come to the conclusion that the most uneconomical boiler was the best one in their plant.

We are now at a point where we should not allow impression to take the place of facts, and we cannot afford to adopt the easiest way if this means an undue loss in economy. As the price of fuel increases, additional capital investment is warranted, and an equipment for securing a higher efficiency usually means more complication and necessitates a higher class of operation than the more simple arrangement. Our best run plants are already on a par with laboratories in the care with which they are operated and the skill and ability of those in charge. There are still, however, many plants where the fuel consumption is 50 to 100 per cent higher than it might be. Each time a wasteful plant is replaced by an economical one we save fuel for future generations and practice real conservation. [W. E. S.]

An Innovation in the Manner of Liming Cane Juice.*

By Maurice Bird.

It has long been recognized that there is a large undetermined loss of sucrose in cane juice during the interval of its expression from the cane and its reception of lime and heat, this loss being due to the acidity and viscous ferments inherent in the juice.

Even washing and liming the mills at night still leaves the rollers, carriers, mill bed, juice channels, etc., subject, during the long hours of grinding, to the action of this acidity and its accompanying ferments.

* From the "Louisiana Planter," Vol. LXVI, p. 184.

As it is largely customary now, in multiple crushing, to return the last mill juice, which contains the bulk of maceration (dilution) water, to the megasse emerging from the first mill, it occurred to me that if this juice were limed and sterilized with formaldehyde, these chemicals would be carried to practically every part of the crushing plant and thereby minimize or entirely remove the loss of sugar at this point.

Above the third mill juice channel, therefore, a cylindrical tank was installed, containing a mechanical stirrer and having a valve at the bottom.

Carefully prepared milk of lime was strained into the cylindrical tank and a pint of formaldehyde added twice a day.

By means of the valve a small stream of milk of lime was allowed to run into the last mill juice which took with it the formaldehyde throughout the crushing plant.

As the results were evidently beneficial, more and more lime was added at this point until the whole of this chemical, needed for clarification, was run in here.

The temperature of the last mill juice at this point, when the lime is added, was 120° F., due to the friction at the rollers and to hot water being used for maceration. It seems, therefore, reasonable to conclude that this clarification in the megasse, as it were, must result in more or less of the precipitated impurities of the juice being strained off by the megasse and consequently relieving the work at the filter presses to a greater or less extent.

That the clarification was greatly improved seemed beyond any doubt, and the sugar cured more easily than previously; also the recovery of sugar from the juice was better, though other causes which happened to exist at this time also aided the increased recovery.

A result that we had not anticipated was that by liming in this way a practically neutral juice could be obtained from the mills, and the annoying and deleterious variation from slight acidity to slight alkalinity and to acidity again, previously experienced, was entirely removed, the least departure from neutrality being easily corrected by regulating the valve admitting the milk of lime to the juice.

Other factories are following our practice of liming the last mill juice, and though of course it might be in vogue elsewhere, I thought, since I have never heard of it before, that it may be novel and that some of the readers of "The Planter" might like to give it a trial. [W. R. M.]

CANEFIELD, *British Guiana,* February 9, 1921.

Report of Committee on Agricultural Progress of the Louisiana Sugar Planters' Association for the Year 1920.*

* * * * * * * * * *

Under the circumstances, the crop had to be grown with field laborers who took full advantage of everything, knowing that they were very much in demand. They received high wages and gave in return a careless and less efficient class of work. The planters had to make the best of the situation, and went ahead with field work meeting all difficulties.

It was the scarcity of labor, high wages, high price of mules and scarcity of feed that caused tractors to come more to the front in 1920. In the fall preparation of land the four-wheeled 12–20 and Thompson plow was used extensively in destroying stubbles and plowing land that was in corn and peavines. In this work the tractor averaged about six acres per day, doing the work of four two-mule plows and one four-mule burster. The two-wheeled tractor with stubble destroyer attachment, with one operation, was used in fall plowing, averaging six to eight acres a day.

The caterpillar type of tractor was used in an extensive way, and from all indications in a greater variety of different works. The Georgia plantation at Mathews used this type of tractor during the entire period of cultivation, also finally laying by the crop. The labor situation in this section became so acute

Labor Shortage and Tractors.

From the time that the first work on the crop started, all through the season cane farmers were confronted with shortage of labor and a high scale of wages. The enormous profits that were made in rice the year before caused a large increase in rice plantings, not only in the rice sections, but also in the sugar territory in the heavy types of land. There were quite a few cases where sacrifices were made in the way of plowing up fair stands of stubble and planting rice.

With these conditions coming up, the demand for field laborers increased to such an extent that changes in the systems of field work on plantations had to be made. There was very little cooperation between the two classes of planters in trying to solve labor problems. The rice planters were bent on planting and growing their crops, and set the pace in paying high wages which sugar planters had to meet by corresponding increases in order to hold their labor. that it was only the use of tractors that enabled the management to successfully cultivate the crop. In these cultivation operations the Magnolia cultivator, equipped with two small turning-plows and a middle burster, was used, and the work performed quicker and better than with mule teams.

There had been so many troubles reported on unsatisfactory tractor operation on account of breakdowns, caused mostly by bad manipulation on the op-

* "Louisiana Planter," Vol. LXVI, pp. 185–189.

erators' part, and lack of proper organization on the plantation, that the system used by the Georgia group of plantations has, in the opinion of the committee, been a marked advance in agriculture progress. Mr. Sommers, the general field manager, with hard work and close attention, devised a system that gave excellent results with tractor work. The entire lot of tractors, eighteen in number, were under the supervision of a tractor mechanic, who was stationed at a repair shed, and devoted his entire time to the repairing and upkeep of tractors. Another mechanic, provided with a truck or car, acted as field runner, and devoted his entire time to see that the tractors were kept in running order in the field. In case of breakdowns or troubles overseers simply called this man, and he either repaired the tractor in the field, or in case of serious trouble moved it to the shed where the mechanic could make the necessary repairs. This system relieved overseers of handling or trying to handle a problem that is new to them, and gave them an opportunity to get more out of their tractors and at the same time attend to other field work.

The implements that were used with the tractors were all rigged up by the plantation blacksmith, and in most cases the regular plantation implements were used. In a way this was a disadvantage, for it left the manager to his own resources to provide implements to use with the tractor, but, on the other hand, it was an economy in saving an expenditure by the use of the old implements instead of purchasing entire new sets of implements. At first preparing the implements presented difficulties, but as the blacksmith worked and gained experience, and besides obtained improvements in shop fixtures and equipment, the work was carried out on a satisfactory basis.

Tractors were used to good advantage in planting cane, going through usual operations:

(1) Two rows opened at one time.

(2) Two rows covered at one time.

(3) Two rows rolled and one middle opened at one time.

In the field work with tractors on Georgia, one man operated the tractor, and one man operated the implement. On account of the strenuous work involved in running a tractor, an entire day was found to be too much of a strain on the operator. An arrangement was made where the tractor and implement operators alternated, each man giving half of the day to running the tractor. This method gave much better results in the way of increasing the efficiency of tractor work.

The opinions of planters regarding the use of tractors on sugar plantations indicate that there is need of a good deal of work on this problem before tractors can be generally accepted for practical field work. From reports received by the committee from different sections of the sugar parishes where tractors were used favorable and unfavorable comments have been made. It is generally conceded by the majority of planters that when tractors are in good running order, they do all classes of field sugar cane work quicker and cheaper than with mule teams. This cost, however, is not at all fixed, and with the frequent stops, breakdowns, high costs of tractor parts, the tractor work is often much more expensive than mule team work.

The question of the right implements to be used with tractors has prevented a more general use of tractors. As a general rule tractors are sold without implements, and the whole thing of equipping the tractor for field work was left to the ingenuity of the planter. On plantations where officials in connection gave this matter some attention, with a lot of trouble, implements were set up and some good work was done. Other planters, not having the time and proper conveniences, only used their tractors in a limited way.

The year 1920 can be termed a good tractor year. The high wage scale, scarcity of labor and high cost of mules, caused a more general use of tractors. On the whole the work performed by tractors last year was far ahead of any other year. In special operations, such as breaking land, laborious discing and hauling, the tractor has surpassed mule teams and can always be used in these lines of work to advantage. With the change in conditions now occurring, wages going down, labor more plentiful, and mules at prewar prices, there will be a keen competition between mule teams and tractors, and supporters of the latter will be compelled to remedy the present day evils for the tractor to make progress on sugar plantations.

CULTIVATION OF CANE WITH TRACTORS AND MAGNOLIA CULTIVATORS.

Date	6–7	6–8	6–10	6–11	6–14	6–15	6–15	6–16	6–29
Number of tractors	12	12	14	13	13	14	14	14	16
Total time, hours	113	106.5	105	151	143	152	149.5	145.5	156
Total Acres	140	118	156.5	177	184.5	196	194	195	204
Gallons gas used	147½	131	153½	189	187	197	194	182	184½
Quarts oil used	26	15½	23	20	23	34	34	45	30
Quarts 600W used	17	17	23	21	17	24	24	34	28
Pounds grease used	11	8	14	13½	12	15½	15½	13	18
Time lost—breakage	4½	3½	..	..	3½	..	..	2	2
Time oiling and adjustment	11	14	18½	22	19½	21½	21	21	21
Average number working hours, 1 tractor	9.4	8.8	7.5	11.6	11	19.8	10.7	10.4	9.8
Average number acres per day, 1 tractor	11.6	8.9	11.1	13.6	14.1	14	13.8	14	12.7
Cost per Acre	72c	76c	65c	72c	66c	66c	67c	67c	64c

Calculations on $4.00 per day for tractor and implement operators.
Gas, 30c per gallon; oil, 30c per quart; grease, 25c per pound.

Fertilization of Cane.

The Extension Division and American Cane Growers' Association conducted co-operative sugar cane fertilizer demonstrations on sugar plantations in 1919. The results of this work helped materially in the fertilization of the 1920 crop in the way of giving planters information on the best sources and amounts of plant food to use in fertilizing their crops. The use of raw materials and a preparation of mixtures on the plantations proved the most economical method and netted savings of $25 to $50 per ton over commercial fertilizers containing the same amount of plant food. Nitrate of soda and calcium cyanamid were the cheapest forms of nitrogen, and it was on the results of the fertilizer

demonstrations that recommendations of the use of the former were made in preference to fertilizer materials that were from 25 to 100 per cent more expensive.

On a large number of plantations fertilizers were applied to both plant and stubble cane. This is quite a change from the old way, as the plant cane is not generally fertilized. The yields of plant cane and stubble were increased and gave returns which warranted the use of fertilizers. However, the storm which occurred in September was very injurious to the cane crop, and damaged the yields about 25 per cent, also causing low sucrose and purity juices. This was one of the main factors that prevented fertilizers from showing up to better advantage.

In the application of fertilizers the committee has obtained reports from several plantations that have made real progress in handling fertilizers. In West Baton Rouge, Cinclare used mixtures of acid phosphate and nitrate of soda in different proportions on various types of lands: The preparation of the mixtures, which is an undertaking that is considered a big job by many planters, was simplified and made rather inexpensive by the use of large wagons and mixing in the field. The wagons were only charged with a limited number of the two kinds of fertilizers, leaving enough room for mixing on the rest of the wagon bed. Each wagon was provided with one extra hand, who, along with the driver, mixed the fertilizer and loaded same directly into the meal boxes as needed. This saved resacking and kept the distributors supplied with fertilizers, so that they averaged ten acres per day.

The Colonial Sugar Company prepared mixtures of acid phosphate and nitrate of soda in a warehouse, and at one end, a small addition was constructed where the fertilizers were screened, crushed and mixed by hand, and resacked. This work was done at a cost of about $1 per ton. Similar mixtures of fertilizers were prepared on somewhat the same basis on the following plantations: Southdown, Sterling, Columbia, St. John, Longview, Laurel Grove and Bellevue.

Calcium cyanamid was used as a source of nitrogen on Raceland and Salsburg Plantations. Acid phosphate was also applied, the two fertilizers, however, being unmixed in two applications. The two application method of fertilizer to cane was found disadvantageous, due to doubling the cost of putting down fertilizer, and causing the use of more teams when they were in great demand for other work at this time.

The management of Salsburg plantations reports excellent results with the use of cyanamid in the way of increased tonnages and giving juices of higher sucrose and purity. A report was also given where it was found that nitrate of soda caused a prolongation in the growth of cane, showing upon anlysis of juice low percentages of sucrose and purity. This condition may have been caused by a late fertilizer application, as results in other sections where cane was fertilized with nitrate of soda early in the season gave good results.

The American Cane Growers' Association and Louisiana State University Extension Division co-operating with the United States Department of Agriculture conducted sugar cane fertilizer demonstrations in the following parishes: Assumption, Ascension, Lafourche, Terrebonne, St. Mary, Iberville, West Baton Rouge, East Baton Rouge, Pointe Coupee, Rapides, and St. Martin. In this

co-operative work the following County Agents took an active part in supervising and getting final results: F. M. Bacque, Lafayette; B. Mackay, Ascension; H. Lesseps, Iberville; R. J. Badon, St. Martin; W. H. Humble, Rapides, and A. B. Curet, Pointe Coupee.

The committee, on request for a complete report on the results of sugar cane fertilizer work carried out in 1920, has been granted this request by Mr. W. H. Chaffe, Secretary of the American Cane Growers' Association, and Mr. W. R. Perkins, Director of Extension, and submits same as an important line of agriculture progress in 1920.

Results of First-Year Stubble.

The best returns were given by a mixture of 300 pounds nitrate of soda and 250 pounds acid phosphate, which showed 12.37 tons per acre more than the check and a net gain of $63.75. Analysis showed good sucrose and purity. A mixture of 200 pounds nitrate of soda and 500 pounds acid phosphate gave increase of 7.89 tons per acre and a net gain of $35.53 per acre.

On Columbia 400 pounds prepared fertilizer, 6.58 per cent nitrogen, gave an increase of 6.6 tons per acre and a net gain of $29.40 per acre.

On David, Evergreen, and St. John plantations, where 300 pounds nitrate of soda were applied on one-acre plots, gave an average increase of 6.73 tons per acre and a net gain of $30.81.

Mixtures of cotton-seed meal, nitrate of soda, and acid phosphate gave good results; 200 pounds cotton-seed meal, 100 pounds nitrate of soda, and 100 pounds acid phosphate gave on David plantation an increase of 6.32 tons per acre and a net gain of $28.38.

Results on Plant Cane.

Special attention is called to mixtures of sulphate of ammonia and acid phosphate. These plots were conducted on one plantation on ¼-acre plots; 150 pounds sulphate of ammonia and 300 pounds acid phosphate gave an increase of 7.85 tons per acre and a net gain of $35.90. One hundred and fifty pounds of sulphate of ammonia and 250 pounds of acid phosphate gave an increase of 5.97 tons per acre and a net gain of $27.05.

In the comparisons between prepared fertilizers and home mixtures the former was given by the Soil Improvement Committee, by their agronomist, Mr. J. C. Pridmore. The committee has gone over the subject with Mr. Pridmore, and find that valuable assistance is being given by the Soil Improvement Committee from an impartial standpoint in soil fertility work to find out the best plant food requirements for growing crops.

A series of fertilizer tests was conducted on plant cane, using one-acre plots, fertilizer at the rate of 400 pounds, 600 pounds, and 800 pounds per acre. The average results from 12 plantations with 400 pounds prepared fertilizer shows an increase of 3.8 tons per acre, and a net gain of $9.72. The 600 pounds application on six plantations shows an average increase of 5.34 tons per acre, and a net gain of $13.14. The 800-pound application showed an increase of only 4.32 tons per acre and a loss of 82c per acre.

Diseases of Sugar Cane.

At the first mention of disease of sugar cane, the new sugar cane mosaic disease, which was first identified in this State in the spring of 1919, has been attracting the most attention. Special surveys have been made in the sugar parishes by the United States Department of Agriculture officials of the Sugar Plant Investigation office during the summers of 1919 and 1920. The American Cane Growers' Association and Louisiana State University Extension Division has also given considerable attention to the Mosaic disease and the following article was prepared on the subject:

Mosaic Disease of Sugar Cane—Infestation.

The mosaic disease of sugar cane was first recognized in this State in the spring of last year. It is very probable that it has been here for a number of years, having been introduced from the tropics through the importation of some new variety of sugar cane. The regions along both sides of the Mississippi River, taking in the parishes of Plaquemines, Orleans, Jefferson, St. Charles, St. John, St. James, Ascension, Iberville, East Baton Rouge, West Baton Rouge, Pointe Coupee, St. Mary, Iberia, St. Martin, and West Feliciana, were found to be infected with mosaic disease. The plantations between Lutcher and Reserve, around Burtville, Gonzales, and Angola, on the east side of the river, are more heavily infected. On the west side the plantations around Waggaman, Vacherie, Lauderdale, Hahnville, and Addis are heavily infected.

Along Bayou Lafourche mosaic occurs on both sides all the way down. Plantations around Belle Alliance, below Napoleonville, Raceland, Mathews, and Lockport are already showing 10 to 20 per cent infections. In Terrebonne the disease seems to be starting, and is not as widespread. The parishes of St. Landry, Lafayette, Vermillion, Avoyelles, and Rapides are free of mosaic.

In comparing the disease at the present time and last year at this time, a general spread is noticeable everywhere. In places where traces occurred infection runs 5 to 10 per cent. Plantations that showed 40 to 50 per cent are now showing 80 to 100 per cent. This is a rather remarkable increase, and shows to what extent it will spread if control measures are not taken.

There are two kinds of mosaic infections, primary and secondary. A primary infection is where the disease is in the seed or cutting and makes its appearance as soon as growth starts. Secondary infection is where the disease is just showing up in previously healthy plants, having been passed during the growing season from diseased to healthy plants. This form of infection is invariably found in the upper or young leaves and is not present in the older lower leaves. Unless a person is especially familiar with this infection, it will be passed up. This condition complicates control work as far as seed selection is concerned, for seed cane having secondary infection will produce mosaic cane. On account of the difficulty of detecting this infection, there is a certain amount of uncertainty in making a sure selection.

The varieties of cane grown in this State are all subject to mosaic disease. D 95 succumbs to the attacks of the disease, and can be classed as an unprofitable cane under mosaic conditions. Infected fields of this variety have a mottled yellow unhealthy color, and generally a noticeable dwarfness or stunted growth.

The latter condition does not always occur in plant cane, but is invariably the case in stubble. D 74 plant cane, with good cultivation, fertilization, and in good land, with heavy mosaic infection makes a good growth. Plant cane under less ideal conditions shows some injury, growing less vigorously. D 74 stubble shows more effects of the disease, attacked plants being of an unhealthy cast, the stripes in the leaves being a decided yellow and sometimes brown color. In a good many cases the cane is stunted and spindling.

Native Canes—Lapice—Striped and Purple.

All three of the varieties are subject to mosaic disease. The plant cane seems to show less injury. In stubble mosaic has somewhat the same effect on these canes as D 95, stunting the growth and giving the cane an unhealthy yellow color. It is quite characteristic to see small stools completely dwarfed by the disease.

Louisiana Seedlings.

L 511, L 243, L 231, all three of these varieties subject to mosaic. The L 511 seems to show some resistance, showing smaller percentage of infection in heavily infected sections. Unlike other varieties, L 511 when attacked with mosaic shows up on the stalks in the form of long, thin, purplish streaks. This characteristic of L 511 was first noticed by Mr. W. G. Taggart and Dr. C. E. Edgerton of the Experiment Station. This would be a valuable point in favor of L 511 in case it should be proven good enough for plantation use, in the way of discarding mosaic seed cane.

Prevention and Eradication.

Mosaic disease has been found to occur on all classes of lands. Heavy infections have been found on virgin soils, and in well cultivated fields. On the other hand, abandoned stubble cane, overgrown with grass and weeds, has been found free of mosaic disease. Poorly drained fields have also been found mosaic free. This is to emphasize that neglected fields, lack of cultivation, and poor lands are not causes of mosaic disease, and also that it does occur on the richest as well as the poorest types of soils.

On places heavily infected with mosaic a special plan will have to be followed to obtain satisfactory results. In such a case it will be almost out of the question to obtain mosaic-free seed cane from the same plantation and selection will not be practical. The use of healthy seed from an uninfected area will be the easiest way. This seed should be planted a safe distance from infected fields (from ¼ to ½ mile). This can be accomplished by separating the fields with leguminous crops, such as velvet beans, soy beans, cowpeas, etc., avoiding such crops as sorghum and corn, which are also subject to mosaic disease. Fields of selected seed cane should be used for planting purposes only, and extended as rapidly as possible, replacing mosaic cane. This is a gradual system and will take several years to eradicate the disease. However, it will easily pay for itself in reseeding plantations with healthy cane, and prevent a coming danger of deteriorated cane, which will eventually be the outcome where mosaic is disregarded.

In cases of light mosaic infection, where the disease is not widespread, the

rogueing method is recommended. This consists in actually getting rid of mosaic plants by digging them out. This method can be used to advantage in preventing further spread of mosaic in stubble cane that is to be used for seed. In such cases the cane should be rogued several times in order to get cases that would develop later on from secondary infection. On the H. C. Minor estate this method is being tried this year on Southdown and Hollywood plantations. The results up to now are very encouraging. Fields that were rogued three times show less than 1 per cent infection, while unrogued fields of the same cane run from 5 to 10 per cent.

The rogueing of plant cane is not recommended unless the infections are very light, in which case it would be a good practice. The growing of second year stubble should be entirely discontinued, due to the fact that mosaic seems to be more virulent in stubble, especially old stubble.

The use of better seed cane, instead of scrappy stubble heavily infected with mosaic, root disease and riddled with borers is another measure that will help in the fight against the disease.

There is no cure for mosaic disease; fertilizer applications, liming, good cultivation, etc., have not stopped the disease. It is a disturbment in the sap of the cane, the cause unknown, which checks normal development of the cane and reduces the tonnage. Mosaic seed cane produces mosaic cane, which spreads during the growing season, diseased plants infecting healthy plants. It seems logical, therefore, for the planter to take the same steps that were taken twenty years ago, when D 74 was distributed in lots of six stalks each to planters over the State for the purpose of replacing the native varieties. Even with this small outlay of seed cane to start on, it did not take many years for large plantations to replace the inferior native canes. Today we are confronted with a threatening danger to all of our cane varieties. Instead of the six-stalk basis, it is possible to obtain mosaic-free cane from uninfected areas in quantities large enough for planters to start on the basis of 5 to 10 acres, under which system it would only take several years to reseed a plantation with clean seed.

Mosaic Disease—Method of Eradication Employed by Estate of H. C. Minor.

"In the early part of 1920 'The Louisiana Planter' brought to our attention the serious consequences resulting from mosaic disease in Porto Rico. A short time later the Agricultural Extension Service sent out a bulletin carrying the same information, and outlined the methods which had been found practicable in combating the disease. However, it was not until we were visited by Mr. Gouaux that we decided to make a fight on mosaic disease along the lines followed in other countries. Our practice was about as follows:

"One of the assistant overseers, whom we felt would give conscientious attention to the work, was designated to stay with Mr. Gouaux until he thoroughly learned to identify mosaic disease. After working one day with Mr. Gouaux he found that it was not always an easy matter to identify the disease, and feeling that he might forget the distinguishing marks, he transplanted four diseased stalks to his garden, which he could study frequently. (A few weeks later a non-diseased stalk was added to the plot. These stalks grew quickly under constant attention, and a few weeks later we noticed that the healthy cane

became infected by contact with the diseased stalks. This plot was used during the year to instruct others who were interested in mosaic disease.)

"Mr. Gouaux at this time spent two days in going over six plantations in the vicinity, and our representative was with him during this interval, and at the end of two days he felt that he could identify the disease with reasonable certainty.

"We found the disease in many widely separated fields, and it was apparently more prevalent in stubble cane than in plant cane. Some fields were more heavily infected than others, but in no case could we find an infection estimated to be greater than 1 per cent. Other fields were apparently free of the disease. At this time, which was about the middle of May, we decided it would not be practicable to rogue the plant cane fields, but would concentrate on those plats of stubble which were freest of disease, and from these plats would come the seed for planting the 1921 crop.

"The plan followed at Hollywood plantation well illustrates the work done, and the costs were accurately kept. The records show that rogueing was commenced June 15th. Two hundred and eight acres of stubble were on the place. While we at first attempted to rogue the whole stubble acreage, we later discarded forty-five acres which were rather heavily infected, and from which we did not intend to use any seed. The assistant overseer before mentioned was put in charge, and he selected one of the white field hands who was known to be honest and painstaking, as the best available man for the job. We thought that one man could eradicate the relatively small amount of diseased cane which we expected to find. He quickly learned to recognize mosaic disease. He carried a spade, and wherever he found a diseased stalk he dug out the stool and dropped the sick cane between the rows. He was able to cover, taking two rows at a time, an average of thirteen acres per day, but to cover it more quickly before the cane got too high to make the work impracticable, this man was given an intelligent boy of 16 years of age, the son of the overseer, as a helper.

"We assumed that once over would be all that was necessary. Such, however, was not the case; here and there over the field a few infected plants were discovered, so a second trip was made, and in places surrounding the spots where the first rogueing was done a number of infected plants were found, which indicated that infection spread before the diseased plants had been cut out. Other places in the field revealed diseased plants, some of which we are very sure were not infected when the first survey was made. The second survey was completed August 25th, and the work was discontinued because the cane was so far advanced in growth that it was not practicable to rogue further. But knowing the many diseased stalks that were present, we determined to eliminate as many as possible when planting began. When we began cutting seed these two men worked among the cutters and threw out all diseased plants which they could identify. We found it was much easier to recognize the sick plants in the later stages than when the work was first begun. We also discovered that it was almost impossible to identify the diseased from the healthy cane while wet with dew or after a rain, so that elimination was never attempted until ideal weather conditions prevailed.

"The accompanying table gives an analysis of the costs. The amount expended is not large. The cost per acre is small. At present we are not able

to say to what extent the work was effective. We are awaiting the development of the coming plant crop with keen interest in this regard, and confess a certain amount of trepidation. For the coming year we expect to continue the work, and feel that if the rogueing method is effective in combating the disease that we can make much better progress in 1921 than in 1920, for many of the employes can now easily identify the disease, and we will not wait until so late in the season to begin work. Already in stubble we can find diseased plants, and by April 1st it is our intention to start rogueing.

Summary of Costs.

Number of days' work put in, June 15th to August 15th, 31.
Total cost for this period, $64.25.
Acreage covered, 208.
Cost per acre, 31 cents.
Days put in during planting season, 12½.
Total cost for this period, $24.
Cost per acre, 11½ cents.
Total cost, $88.25, or 42½ cents per acre.

Cover Crop for Fall Plant Cane.

The growing of a cover crop on all plant cane is a work of the Louisiana Sugar Experiment Station. The results of the experiments conducted at the station during a period of years show an increase of about four tons per acre on fall cane where clover was grown as a cover crop on fall cane, and turned under in the spring, over fall cane where no cover crop was used.

This good work of the experiment station, which had only been discussed and not used in a practical way, was started on a small scale by Mr. S. F. Morse on plantations in the State. From results of 1919, the acreages of the fall cover crop were increased on the following plantations: Reserve, Colonial Sugars Company, Raceland, Salsburg, and J. Van Beary & Co.

On plantations where the cover crop was used last year the acreages on this year's fall cane were increased, some plantations planting 300 to 400 acres. From all reports received, the clover cover crop is giving good results. At first planters were inclined to think that a dense growth of clover on the cane would conserve too much moisture and seriously impair cane stands. The reports received during the two years tried out show no injuries from this source.

The clover used for the cover crop is known as *Melilotus indica*. It is an annual sweet clover with a yellow blossom, known as sour clover in the west. This clover is different from *Melilotus officinalis*, a biennial yellow blossom sweet clover growing on ditchbanks in Louisiana.

In planting *Melilotus indica*, 18 pounds of seed per acre is used. The seed is sown by hand after the cane is covered, and the cane is rolled in the usual way.

Field and Hay Crops.

Early in the year planters were compelled to buy corn and hay for their mules, due to the severe shortage occasioned by poor crops. A good many of the planters purchased ready mixed feeds. From reports where such purchases

were made, the purchase of the ingredients in the form of corn, oats, cotton seed meal, etc., and preparation on the plantation would have netted savings of from 25 to 30 per cent over ready prepared feeds. This is generally the case, and the attention of planters is called to the savings that can be made in preparing feeds on the plantations.

The growing of hay crops on sugar plantations was undertaken on a large scale in 1920. The heavy types of land which are so uncertain for sugar cane were used extensively for growing hay crops.

Alfalfa was one of the most popular crops. Where the land was well prepared, drained properly and the seed sown in October, good stands of alfalfa were obtained. Longwood plantation in East Baton Rouge reports four to five cuttings per acre, averaging about one ton to the cutting. Other plantations along Bayou Lafourche report equally as good returns.

Sudan grass gave excellent results on Sterling and Glenwood plantations. The seed was sown broadcast at the rate of 20 pounds per acre on twenty-foot beds in the latter part of March and early April. Yields of three to four tons per acre were produced. The hay was found especially palatable for mules and easy to harvest and cure.

Mixtures of alfalfa, alsike clover and oats were also planted early in fall and promises to give good results as an early feed.

Corn and Cowpeas.

Outside of the regular methods used in growing corn on sugar plantations, there was very little progress reported in this line of work. There is a general need of an increased production of corn on sugar plantations, in order to meet the need of providing sufficient corn for working mules. In Iberville parish, Clifton and LeBlanc, on Bellefort plantation, with the use of a mixture of nitrate of soda and acid phosphate, report an increase of about 60 per cent in corn yields. The application of fertilizer to corn is one of the corrections that could be made in the old method to increase production.

Cowpeas.

The Brabham variety of cowpeas was tried on a good scale by a number of planters. This cowpea has a very small round seed, which naturally makes one bushel go further than the larger seed varieties. The Brabham compares very favorably with the high class clay pea, and from reports made to the committee it is just as good. The seeds germinate well and produce a heavy growth of vines.

Varieties of Cane.

The variety of D 74 regained most of the popularity it lost in 1919, when unfavorable conditions caused unusually low yields. From the standpoint of the keeping quality of seed cane, D 74 proved its superiority over the native canes. In practically all cases where there were poor stands of cane, the fields were planted with native varieties. In the fall of 1920 acreages of D 74 were increased and the native varieties were planted on a much smaller scale. The only sections where native cane is still popular is in Lafayette and Rapides parishes, where the cane is giving good results.

Louisiana Seedlings.

The work with seedling canes, since the occurrence of mosaic disease in Louisiana, has not made the usual progress. Glenwood plantation at Napoleonville have increased their L 511 cane acreage to about four acres. The following handmill tests were made in November:

Variety	Brix	Sucrose	Purity
L 511	16.47	12.97	78.70
L 253	11.93	7.05	59.2
D 74	14.47	10.93	75.5
Louisiana Purple	14.27	10.27	71.6

In the St. Mary section the following handmill tests were made in October:

Plantation	Variety	Brix	Sucrose	Purity	Acidity
Columbia	L 511	15.43	12.24	79.2	.55
Oaklawn	L 511	14.11	10.61	75.05	.75
Sterling	L 511	16.36	13.69	83.50	.60
Oaklawn	D 74	14.96	11.24	75.05	.55
Sterling	D 74	15.82	12.11	76.30	1.10
Oaklawn	La. Pur.	16.17	13.09	80.90	1.00

L 511 is still promising to give good results, and efforts are being made to increase the acreage of this cane as much as possible.

L 253 and L 231 are giving good results in producing heavy tonnages. Both of these canes have a tendency to mature late, and produced low sucrose and purity juices when analyzed in October and November. A closer study on these canes is necessary before they can be finally rejected or accepted for plantation purposes.

Sugar Cane Borers.

There were a good many complaints of the injuries caused by cane borers in the river parishes and in Lafayette, Iberia, and St. Mary parishes. On Homestead plantation in West Baton Rouge and Southdown in Terrebonne the percentage of borer infestation has been reduced to a considerable extent by planting cane in the fall. From reports received sections doing a lot of spring planting were more troubled with borers.

In the spring of the year Mr. T. C. Barber, entomologist of the United States Department of Agriculture, along with several assistants, spent some time in Cuba collecting Tachnid flies (Pupae) and sending them to Louisiana for release in cane fields. The fly is a natural parasite of the cane borer occurring in Cuba, where it keeps the borer under control. Planters in the State made contributions and the Department of Agriculture co-operated and sent Mr. Barber to Cuba in charge of the work.

The parasitic flies were released on plantations in the State during the summer months. The work of this beneficial insect is being closely watched to see whether they would winter over and propagate satisfactorily. From reports

obtained so far the parasites live through the winter. Care is also being exercised in the way of not burning cane trash where releases have been made, so as to protect the parasites as much as possible.

The committee has endeavored to report on lines of agricultural progress that have taken place in the year 1920. There were a good many general improvements on plantations all over the sugar parishes in the way of repairing and painting of quarters and outbuildings, remodeling and weevil-proofing corn bins, remodeling barns, construction of new sheds and fences.

There has also been a lot of good work done in improving the system of accounting and the keeping of proper records. The successful operation of plantations is so dependent on proper systems of accounting that planters are devoting more time to correcting faults of the old system and introducing new systems that will guide them in their work and prevent them from suffering losses that they have been more subject to with the old systems.

In conclusion, the committee wishes to emphasize the need of more co-operative work on agricultural problems of sugar cane. The American Cane Growers' Association and Louisiana State University Extension Division plan to work more along these lines. The State experiment stations are also joining in the work and are planning to conduct co-operative sugar cane and rice fertilizer demonstrations with planters. Besides this the soil improvement committee will also co-operate in the work. With this plan of work ahead and with the proper interest of planters the work in 1921 should surpass in progress the work of the past years.

Respectfully submitted,

C. B. Gouaux,
J. M. Caffery,
Elliott Jones,
Committee on Agricultural Progress.

[J. A. V.]

Common Sugar Cane, *Saccharum officinarum.**

Natural Order Gramina: nat. both Indies. This plant and its cultivation has been so long known in the West Indies, that it will be needless to say much of it. There are several species cultivated in the Island (Jamaica), which suit the various soils and climates. There are also varieties of this cane both as to size of the joints and colour; some being a yellowish white, and long jointed, others red and shorter jointed, and another sort Elephantine, with the culm thick, and knots approximate. There is also the Ribbon cane, the culm of which is curiously striped and variegated; but not much esteemed. The Otaheite and Bourbon canes are now very much cultivated, and found to be very productive.

* From Titford, Sketches towards a Hortus Botanicus Americanus, p. 37. (Published in 1811.)

In preparing the ground for planting, the plow is not yet used so much as it might be, and one would suppose with the most beneficial effect. There are ten other species. The virtues of sugar are attenuant, pectoral, vulnerary, and in a high degree nutritious. Muscovado sugar, with Cocoa nut oil, is fatal to worms. A species of wild cane in Jamaica makes an excellent pickle.

[E. L. C.]

The Sugar-Cane; *Lat.* Arundo Saccharifera.†

As it would be more curious than requisite, to examine the several controversial Opinions, whether Canes were originally the Growth of the *East* or *West Indies*; I shall therefore proceed to observe, that in the Manner of their Growth, Form of their Flags or Leaves, and Make of their* Pannicle, they resemble the Reeds which grow in wet marshy Grounds in *England* or elsewhere; however, with this general Difference, that the Sugar-Canes are every Way far larger; and the Inside, instead of being hollow, is full of white Pith, containing a very sweet Liquid. The intermediate Distance between each Joint of a Cane is of different Lengths, according to the Nature of the Soil, Richness of the Manure, and seasonable Weather during their Growth; but in general from one to four Inches long, and from half an Inch to an Inch Diameter, seldom more. The Length of the whole Cane likewise depends upon the above Circumstances. It generally grows to Perfection in about fourteen Months, its then Height (the top Flag-part excluded) is from three and a half to seven Feet, a Medium between both being the most common Length, even in a very good Soil, and seasonable Years. The Body of the Cane is strong, but brittle, of a very fine Straw-color, inclinable to a Yellow. The Extremity of each, for a considerable Length, is cloathed with many long reed-like Leaves, or Blades, whose Edges are very finely and sharply serrated: And the middle longitudinal Rib in each is high and prominent.

F. *Labat,* in his History, says, that there were Canes in the Island of *Tobago,* of twenty-four Feet in Length: If he meant this in general, his Assertion is a strong Specimen of that Vanity, to say no worse, which influences many Writers to be fond of Relations of the marvelous Kind. But whoever judges

† Hughes, The Natural History of Barbados, Book VIII, pp. 244-252. (Published in 1750.)

* There are but few Canes, especially if they grow in a deep Soil, that shoot out into an Arrow decorated at the Top with a Pannicle; and those that do, grow generally in a shallow Soil; tho' the Glumes of their Pannicles contain a whitish Dust, or rather Seed: Yet these, being sowed, never germinate.

The most natural, and perhaps the only proper, Method of producing Canes is by Suckers, or, as Experience shews, with the tender Tops of old Canes: These being cut into Pieces of about a Foot long, and planted in Holes of about six Inches deep, and two Feet wide, and covered with good Manure, each Piece will produce from its Roots a great Number of Canes.

of the Length of Sugar-Canes, in general, from these Instances, if there were any such, may as reasonably conclude from the Height of one *Goliah,* that the *Philistines* were in general of a gigantic Stature.

Whatsoever Difference some Soils, and very seasonable Weather, may occasion in the Growth of this Plant; yet in this all Writers agree, that it is (unhappily for the Planter) liable to one Disorder hitherto incurable, that is, the Yellow Blast.

This, among Diseases peculiar to Canes, as the Plague among those which happen to Men, too justly claims the horrible Precedence.

And as the Ingenious in this Part of the World have not as yet agreed in their Opinions about the Cause of this destructive Blast, I may without any Apology (I hope) offer my own; *i. e.* That it proceeds from Swarms of little Insects, at first invisible to the naked Eye; and as the Juice of the Cane is their proper Food, they, in Search of it, wound the tender Blades of the Cane, and consequently destroy the Vessels. Hence the Circulation being impeded, the Growth of the Plant is checked; and soon after it withers, decays, or dies, in proportion to their Degree of Ravage.

From this Supposition we may easily account for the various Phaenomena, which attend the Blast, whether in its first Appearance, or its further Progress. It is difficult to distinguish the Blast in its Infancy, from the Effect of dry Weather; the Appearance in some Instances seems to be alike: However, the first seasonable Rain manifests the Difference; the uninfected Plant reaps the Benefit of it, thrives and flourishes with great Vigour; whilst the infected, being made more soft and tender by the Rain, becomes easier to be pierced by the devouring Worms. At such and other times, there are often seen, on the Blades of such sickly Canes, many small protuberant Knobs, of a soft downy Substance, often containing in them small white Maggots, which, I believe, turn afterwards into small brownish Moths, which are to be seen in great Multitudes among the Blades of infected Canes. It is likewise observable, that such Blades will be full of brownish decaying Spots: These are so many Places, which have been deeper pierced by the Worms.

Multitudes of Ants are likewise seen on the blasted Canes; these are invited hither to suck the Juice that ouses out of the wounded Leaves, especially when the Plant hath attained any Degree of* Sweetness. This appears by the Clamminess, that, at such times, covers the Leaves, preventing all Perspiration. In this lacerated Condition of the Plant, the Juices want their natural free progressive Motion upwards; the most subtile and finest Part bursting through the wounded Leaves, whilst the more gross returns back unsecreted to the radical Vessels. By this means they are overloaded, and, bursting, supply the Ants at the Roots with a nourishing Liquid. In this injured Condition the Roots become incapable

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* Perhaps the Attendance of the Ants may proceed from two Causes: They may be invited, as above-mentioned, when the Canes have attained some Degree of Maturity by the sweet Juice, which ouses out of the Wounds, as may be perceived by the Clamminess of the Blades; or, if this is not the Case, when the Plant is very young, they may perhaps be allured to prey upon the dead and living Bodies of these little Animals infesting the Canes.

of supplying the Stalk or Leaves with Nourishment from the Earth, if the latter should ever recover.

The Blast is observed to be most frequent in very dry Years, there having been but little of it when seasonable Rains have begun early, and continued till the Canes were ripe. In such Years, a great many of these Vermin are perhaps drowned by the heavy Rains, as well as their Eggs made less prolific.

It is observable, that the Blast usually appears successively in the same Fields, and often in the very same Spot of Land: It is therefore very likely, that these are but the successive Offspring of Parent-Eggs, from time to time deposited there by the small brown Moths above-mentioned. And when the Blast is found in Fields of Canes, far from infected Places, we may, in all Probability, conclude, that the Eggs were conveyed thither by the Wind. What makes this more evident is, that the Infection always spreads faster to the Leeward, or with the Wind.

It is remarkable, that if Canes have been once infected with the Blast, although they afterwards, to all Appearance, seem to recover; yet the Juice of such Canes will neither afford so much Sugar, nor so good of its Kind, as if obtained from Canes that were never infected. I conceive that, in this Case, the delicate Strainers, adapted to secrete the Particles, which constitute the Sugar, have been so much injured, as not to be in a Condition to perform their Offices to Perfection, although sufficient to sustain the Plant alive, and in a seeming Vigour.

Should it be asked, If this Blast is occasioned by Worms, how comes it to pass, that the adjoining, and often the intermixt Corn and Pulse should be free from it? it may be easily accounted for from similar Instances in *England,* where the small Worms, causing the Blight or Blast, which destroys the tender Buds of Apple-trees, never affects the Pear or Cherry-trees, tho' in the same Orchard; for, in all probability, neither of these affords a proper Nourishment for them.

Having thus, till better Reasons are offered, shewed the Nature of the Disease, the next Thing necessary will be to look for a Cure.

Hoc Opus, hic Labor est.

Various are the laudable Endeavors to this End, which the Inquisitive in this and the neighboring Islands have made; but, alas! made in vain: Therefore, as this Disease hath been hitherto of the Number of those which are incurable, and almost literally as destructive to us, and our neighbouring Islands, as the Locusts were to the *Egyptians*; a studious Attempt to remove so great an Evil, will, I dare say, meet with the Approbation of every Well-wisher to our *West-India* Islands; especially since what I have to offer upon this Subject is attended with the strongest Probability of Success: And as it requires very little Experience, and less Labour, I may with more Confidence venture to recommend it to the Public.

When the Canes appear to be first infected, which happens generally when they are young, take an equal Quantity of Brimstone, Aloes, and the Bark of bitter Wood; let these be put in the Middle of a Bundle of wet Straw; the Whole must be put in a Cradle of Wire as large or larger than the Crown of a Hat, made Lattice or Net-fashion; this is to be fastened to a wooden Handle of

convenient Length, and kept to the Windward of the infected Bunch of Cane, having first set the inclosed Combustibles on Fire; and holding it there till the thick Smoke hath for some time penetrated among all the infected Blades, and so on to the rest, for a few Mornings and Evenings: This by its very Nature cannot fail of killing those minute Animalcules, as well as destroying those that are in Embryo in those downy *Nidus's* already mentioned. Experience, which is the most convincing of Proofs, gives a strong Sanction to this Method; for we find, that the Smoke of Brimstone, in an inclosed Room full of Flour, pestered with Wevils, will, in a few Minutes, intirely destroy them. If then Wevils, which have a strong scaly Covering, and are grown to their full Strength, can be thus destroyed; how much more probable is it, that such tender small Animalcules may likewise, in the same manner, be destroyed? If it be said, that in the former the Smoke is more confined, it must likewise be considered, that a far weaker Degree of this sulphureous Smoke will destroy Animals of a far weaker Texture, and perhaps of but a few Days old. The Necessity and Use of the other Ingredients of the same Nature are too evident to be further explained.

The Cane-plant being described, and the Diseases of it considered, and a more than probable Remedy proposed, I shall proceed barely to touch on the Method of making Sugar. The* Canes, when ripe, are squeezed between the iron-cased Rollers of Wind-mills, or Cattle-mills. The Juice thus pressed out is boiled first in a very large Copper or Chaldron, mixed with a very small Quantity of Lime. When this is used in too small a Proportion at first, a little Lime-water may be afterwards poured into the Chaldron. A strong *Lixivium* of Ashes will perform the Office of white Lime, and may be substituted in the Room of it; and was originally used, tho' the latter is generally thought to be more efficacious. It is probable, that the Benefits arising from either are, in great measure, owing to their alcaline Qualities. The Sugar-cane, when ripe, is of all other Plants the sweetest; however, there is a latent Acid still lurking in the Juice; this is apparent by its turning sour, if suffered to remain unboiled any considerable Time after Expression. The Addition therefore of *Temper*, as the Planters call it, being a certain Quantity of white Lime, is necessary to destroy, in a great measure, the remaining Acid, and to form a neutral Salt.

That this is one Use of *Temper*, is plain from the different Quantities of that which are used according to the different Qualities of the Cane-juice:

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* If, when Canes are ripe, the Weather should prove very rainy, their Juice, if at that time expressed, will require a far longer Boiling, before it comes to the Consistency of Sugar, than if it had been extracted in Weather moderately dry. However, this Difference in the Quality doth not intirely proceed, as it is generally supposed, from the greater Quantity of Water at that time in the Plant, but from the greater Number of newly sprung up Particles, occasioned by the late Rain. These, if soon afterwards expressed, having not had sufficient time to ripen; the Make of their Particles is, as in all Acids, angular, and sharp-pointed, and therefore dissimilar to those ripe ones: They will therefore resist the Heat longer before they are broken, and brought to such a Consistency as to incorporate with the others that are already ripe. From such a Mixture of ripe and unripe Juices, it naturally follows, that the Sugar then made will be neither of equal Consistency nor Goodness with that made in seasonable Weather, and from Canes grown kindly ripe.

That from unripe Canes, as more abounding with Acids, requires a larger Quantity, as doth that also from Canes too ripe, and tainted: For in the latter the acid Salts, that before were neutralized, seem to be again disengaged, and set at Liberty, as may be discovered by its acid Taste. And indeed many Instances occur in making Sugar, which demand an extraordinary Proportion of Lime; all these betray a Tendency to an Acidity in the Juice: But, when the Canes grow kindly ripe, the acid Particles in their Juice are few; and as the Poignancy of these is inconsiderable, the Juice will consequently require a less Quantity of Lime. There is a further Use in Lime, besides the foregoing; for it suits greatly in cleansing the Liquor.

When the Quantity of Lime is duly proportioned, if the Liquor is put into a Glass, an immediate Separation will follow, the Impurities settling to the Bottom, leaving the clear Juice at the Top: But if there is a Deficiency of *Temper,* the Separation will be imperfect: If it too much abounds, there will be little or no Separation at all.

When the Lime is mixed with the Juice in the Copper or Chaldron, the *Sordes* or Impurities, being no longer intimately united with the boiling Liquor, and being forced about with the Heat of the Fire, are easily entangled in a viscous Substance that is naturally in the Cane-juice; and then rise with it to the top of the Copper, forming a thick tough Scum.

This Viscidity is very apparently discovered on the leaden Beds of the Mills, as well as on the wooden Gutters, where the Juice in its Passage deposits it; and its* saponaceous Quality is no less evident in washing the Cloths that have been any ways used in cleaning the Beds of the Mills, or hath any other way been soaked in the Cane-juice.

The Clarification of the Liquor, as far as it is done in the first Copper, is perfected after the more gross Scum is taken off; the remaining Impurity, as the Liquor boils, is skimmed off from the four or five remaining Coppers or Taches, into which the Liquor is successively poured; each of these being gradually less, as they are to contain a Quantity of Liquor still wasting as it boils.

In conveying this to the fourth Copper, it is in its Passage strained thro' a thick Woolen Cloth, where it leaves all the Remainder of its Impurities, that had escaped the Scummer.

After this a light white Scum is taken off; and, when this ceases to arise in any considerable Quantity, and the Liquor, by long boiling, becomes more of a Syrup than a thin Liquid, it is then poured into the first Tache, and from this to a lesser, till it is conveyed to the last. When it hath here attained the due Consistence necessary to become Sugar; it may be asserted in general, that no more than a seventh Part of the Whole remains; which Diminution is occasioned by the Impurities being scummed off, and the watery Particles evaporated.

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* This saponaceous Quality in the Cane-juice is capable of resolving viscid Concretions: It is to this, chiefly, that we may attribute the surprising quick Recovery of those sickly Negroes, who are permitted to drink freely of this Cane-juice when intirely ripe. It is likewise so nourishing, that Slaves have subsisted upon this alone for a whole Week.

Repeated Draughts of it are very efficacious, to remove the Effect of the poisonous Cassado-juice.

From this Juice likewise, when mixed with Water, and fermented, is made a Drink, called the Sugar-Drink. This, tho' it appears muddy, yet is very wholesome and diuretic.

From this last Stage, whilst of the Consistency of a thick granulated Syrup, it is conveyed into a large Brass Cooler, where it begins, as it cools, to shoot into Crystals, which are the genuine and essential Salts of the Plant. These are forwarded and helped to shoot, by gently stirring the whole Mass; by which means the Air is admitted to every Part, and the Particles of Sugar disengage themselves from the clammy Substance of the Melasses.

If the Syrup be continued longer on the Fire, than is necessary to bring it to a proper Thickness, the Particles of Sugar cannot grain, or crystallize, when afterwards in the Cooler, for want of a sufficient intermediate Fluid; the whole Mass in such a case being too well united, to suffer the Melasses to separate from it.

On the other hand, if the Syrup hath not undergone a sufficient Evaporation, the Grains or Salts will be larger indeed, but close to each other; Hence several of them being too much separated from their neighbouring Particles, they become too weak to resist singly, and are therefore drained away in the intermediate Fluid, the Melasses. Upon this Principle we may account for the Make of Sugar-candy, whose large Crystals are obtained from a Syrup too thin to shoot into Salts capable of uniting close together.

The proper Time to remove it from the Cooler to the Pots or Moulds, is when it hath grained or crystallized; the better the Sugar is, the sooner this is completed: Hence that just, but ill-expressed Notion, that good Sugar may be potted sooner than bad. The Pots or Moulds made use of are earthen, and of a pyramidal Form, containing from eight to thirteen Gallons.

About twenty-four Hours after the Sugar is potted, the small round Hole in the Bottom of each Pot is unstopped, and the Pots put upon earthen Jars containing about four Gallons, into which Vessels the Melasses drain from the Sugar, the latter becoming fit for Exportation in about a Month's time, and sometimes sooner. The Sugar in this Degree of Perfection is called *Muscovado,* which is a Term too well known to want any further Explanation. What is called here clayed Sugar, is brought to that Degree of Whiteness, by making a Batter of the softest finest white Clay mixed with Water: And after the upper Part of the *Muscovado* Sugar in the above-mentioned earthen Pots is dug up, and closely laid on again in a level Manner, or rather somewhat shelving towards the Middle, a sufficient Layer of this Batter is poured upon the Top of the Sugar in the Pot. The Water from this by Degrees gently ouses from the Clay, thro' the Sugar; and when all the Moisture from the Clay is absorbed by it, which is generally done in about a Month's time, another Layer of fresh Putty is laid on, the former old one being first taken away. In about five Weeks after the latter is put on, this becomes dry, and is taken off; and the Water issuing from it meeting with less gross Viscidities than the former, washes the Particles of Sugar clean, and carries away with it those less feculent Impurities. This completes the Work, as far as it is manufactured here; tho' this is brought to a far greater Degree of Whiteness and Perfection in *England*.

Out of the above-mentioned Skimmings, when mixed with a certain Quantity of Water and Melasses, and fermented, is extracted that spiritous Liquor

called Rum. And from the great Quantity of Oil in the Cane-juice, which is considerably transmitted to the Rum, proceeds the Excellency of this Spirit, when compared with Brandy: The latter, wanting this Oiliness, stimulates and lacerates the Coats of the Stomach; whereas the former, if first meliorated by Age, and made into weak Punch, and drank moderately, by its Oiliness preserves the Bowels.

Most of our Planters are yearly great Sufferers (especially when they first begin to distil) for want of proper Knowledge how to raise and continue a regular Fermentation in the *Mulsa* intended for Distillation: Yet I imagine, that their want of Success may not only be accounted for, but likewise remedied.

In order to do this with Certainty, we must observe, that no Fermentation can be raised under thirty-six Degrees of Heat, or kept up after ninety; a lesser than the former will not be sufficiently warm to raise an Ebullition, and a greater than the latter dissipates the spiritous Particles too much. Therefore if Experiments were made with a Thermometer in every Distil-house, to fix the certain Degree of Heat, that a well-proportioned *Mulsa* would ferment in, it would be easy, by the Help of this Instrument, always afterwards to ascertain this necessary Degree of Heat, let the Change of Weather be ever so sudden or considerable. For if the Heat proved so great as to exceed that Degree, in which such a well-proportioned *Mulsa* was used in Time past to ferment best, then the Windows towards the East ought to be opened so as to admit such a Quantity of cold Air as would reduce the Heat to a proper Standard.

On the contrary, if the Spirit in the Thermometer sinks below the necessary Degree of Heat, then these Windows ought to be intirely or partially shut up, in order to procure a sufficient Degree of Heat. By this means the Distiller may come to a Certainty, and proceed by Rule, and not by Chance.

If after such Rules, and necessary Cautions, the *Mulsa* doth not ferment, if this happens in the Beginning of the Crop; such a Failure ought to be attributed to the then, comparatively speaking, sour and unripe Juices of the Canes: for the Juices of these, as well as most, if not all other unripe Fruits, witness that of the Grape, seldom or never ferment well; because their Particles, in that unripe State, are not sufficiently meliorated by the Heat of the Sun. In such a Case, I am apt to believe, that a greater Proportion of Sweetening, than when the Canes are ripe, should be added to the *Mulsa*.

On the other hand, a disproportionate Quantity of Sweets, as they are Oily, will prove too inactive, and will incline the Liquor more to a Rancidity, than Fermentation: Therefore a greater Quantity of Water, and thin returned Liquor, which hath a great deal of Acidity in it, should be added to the Skimmings of Canes that are full-ripe, and consequently very sweet.

As to those who keep their fermenting Vessels in the open Air, or ill-covered under Sheds, their bad Success may be evidently accounted for, by the Inequality of the Heat and Cold they are exposed to.

I cannot conclude the Description of this very useful Plant, without taking Notice of a most surprising Instance of the Effect of some Effluvia, or Vapours that arose from the Mudgeon or Dregs of the Liquor returned from the Still, and which for some time had been reserved in a Cistern.

In the Month of *April* 1743. *Abel Alleyne,* Esq; the then Manager at the Estate of the Honorable and Reverend Society for propagating the Gospel in foreign Parts, ordered one of the Cisterns, which the returned Liquor was kept in, to be cleansed: The Quantity of this thick Sediment in it was not above seven Inches deep. The first Negro Slave who attempted to clean it, was no sooner at the Bottom, than dead; the second and third met with the same Fate instantly. A white Person, who was a Workman on the Estate, being near at hand, determined, if possible, to bring them up, imagining they were only in a swooning Fit. To this Purpose he went down to the Bottom of the Cistern, which was about nine Feet deep, and found the Negroes dead: He went down a second time with a Rope, in order to fling it about them, and to bring them up; but he had no sooner reached the Bottom, but a sulphureous suffocating warm Blast took away his Senses, and he was taken up for dead; however, being blooded, though he was for a long time afterwards very sickly, yet he at last recovered. The best Method of dissipating these noxious Vapours is to admit into them a free Circulation of the Air, as well as to pour in, by Gutters, a considerable Quantity of Water. This Plant is delineated in Plate XXIII. Fig. 1.

[E. L. C.]

Sugar Cane Seedling Work in India.*

By Dr. C. A. Barber, C.I.E.

PART I.

The present note was first suggested by some queries as to the arrowing of the sugar cane in the South African Sugar Journal of August and September, 1919. The cane does not appear to arrow freely in Natal and a more frequent occurrence than usual naturally led to speculations as to possible seedling work there, with the idea of improving the stability of the Uba cane, which is the main kind grown. Arrows were collected and have been sown and the results are awaited. It is quite possible that this experiment may turn out unsuccessful for, as will be seen, the arrows of members of the Uba class are sterile in India and they may also be so in Natal; but this is no reason why this important work should be given up there, for there are many lines of work open, some of which will undoubtedly suggest themselves to the officers in charge of the experiment stations after reading this account of the Indian work. A further reason for publishing a resumé of the Indian work is that it would appear to be unknown to the workers in the New World, for there is an absence of references to it in recent accounts of seedling work there. This, of course, does not apply to the West Indian and British Guiana publications, in which the foundations of cane seedling work were laid down many years ago, but to places which have more recently commenced to raise seedlings, as in Porto Rico and Argentina, where

* Inter. Sugar Jour., May, 1920, pp. 251-257.


Plate. 23. Page 252
Fig. 2
Fig. 3
Fig. 1
NEC CUPIAS NEC METUAS
To the Honourable
Coll. Yorke,
this Plate is humbly inscrib'd
&c.

the studies are still in their initial stages. In one respect the work in India, carried out at the Coimbatore Cane-breeding Station, is unique, and that is that it was not a question of merely raising cane from thick tropical parents, but of obtaining definite crosses between these and the many thin, indigenous Indian canes; and not only so, but of obtaining sets of seedlings suited to the very different conditions in the sugar tracts of this great country. This use of Indian canes as parents has greatly broadened the outlook and many facts have come to light which have not been noted in the ordinary seedling work hitherto carried out in different parts of the world. It has, for instance, been found quite feasible to use the wild Saccharums as parents, and some of the children obtained by crossing these with cultivated canes appear to be of high promise, but in vigor and sucrose content, especially for those parts which are liable to injury from frost or drought.

The Possibility of Producing Cane Seedlings in India.

A considerable amount of work has been done on this subject at Coimbatore and various references to it have been published from time to time, but a specially useful article appeared from the pen of Mr. T. S. Venkataraman in a recent number of the Agricultural Journal of India, in which he summarizes most of the work on cane arrowing. The main line of work set for themselves by the officers of the Cane-breeding Station was to produce seedling canes which could with advantage replace the host of inferior kinds grown in the millions of acres of the North Indian sugar tract.[1] When the station was started, seedling canes had not been produced in India, with the possible exception of a few which died in infancy at the Samalkota Sugar Station some dozen years ago. This was not because attempts had not been made, and it was suggested that the extreme dryness of the air might have withered the pollen or ovaries in the flowers. On the appointment of a whole time officer, however, the question was at once taken up. In the Christmas holidays of 1911 a number of arrows was collected and sown in some 300 pans at Coimbatore. A mass of seedlings was soon observed, but most of these turned out to be grasses and, finally, only 11 undoubted cane seedlings were produced. The flowering period was practically past and it was proposed to leave the matter over until the next year, but a study of the inflorescence used showed that most of the stamens were unopened and the available herbarium material was examined to see if there were any kinds in which this was not the case. The flowers of three kinds were found to have open anthers and, after some correspondence, a set of arrows was received from Bangalore of one of these kinds, and was immediately sown, with the result that 50 healthy seedlings were easily obtained. As a result of further study it was found that, when the anthers were open, there was abundance of good pollen present, but when they were closed they merely contained a mass of undeveloped pollen mother cells. The Java test was applied, in which the presence of starch

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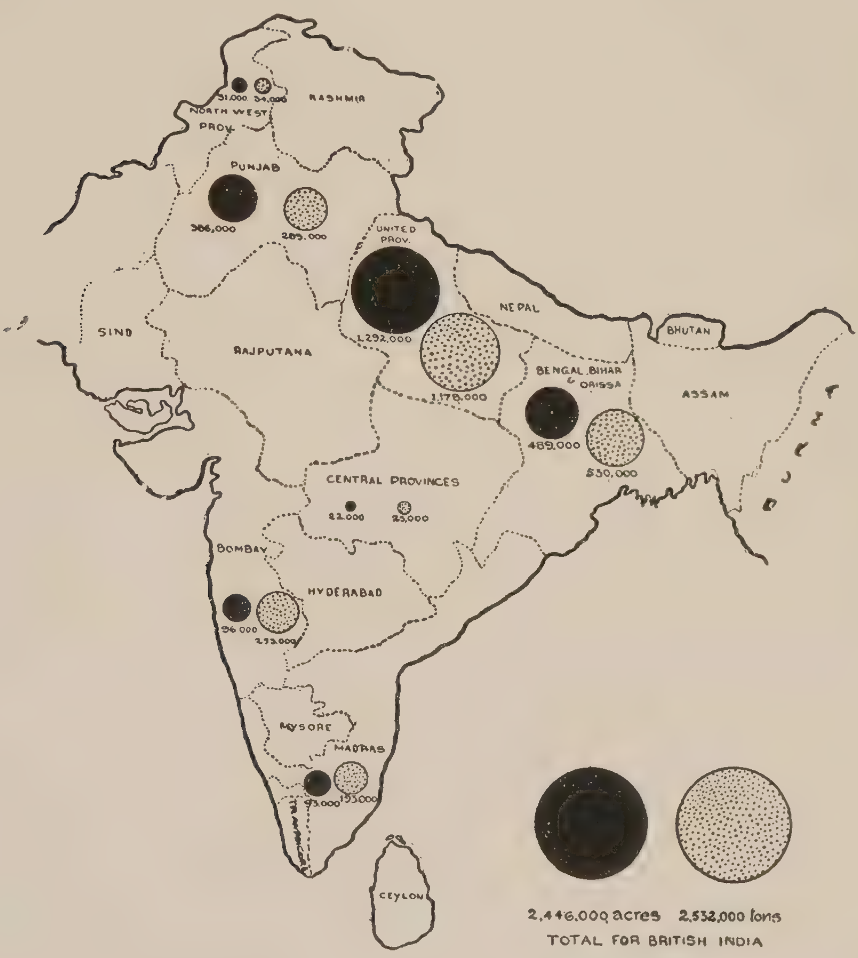
[1] The relative importance of the two sugar cane tracts of India can be judged by a reference to the accompanying map, reproduced from Bulletin No. 94 of the Agricultural Research Institute, Pusa, 1920, by T. S. Venkataraman, B.A., Acting Government Sugar Cane Expert, Madras.

grains in the pollen indicated fertility and it was found that in every case the open anthers had such pollen while in the closed anthers no starch was present in the pollen grains even if they were formed. Open anthers thus would appear to be the sign of male fertility, and this recalled an observation made some years previously by the writer on the cropping of pepper (*Piper nigrum*) on the west coast. It was noted there, for a vine to bear, it was necessary for open anthers to be present in abundance, and it was also noticed that, once the anthers had opened they remained so permanently, so that the fertility of a plant could be



Map showing the two sugar cane tracts of India.

determined years after in herbarium specimens. This experience was applied to the sugar cane arrows, and the same fact was noted and, in place of the somewhat tedious Java iodine method, the presence of open anthers was taken as the sign of fertility of the male organs. It was at once applied to the arrows in use or received in correspondence, and this was easy, as the examination of the inflorescences could be postponed for months and did not need to be undertaken until the rush of the work during the flowering period was over. Every arrow used

for the production of seedlings was submitted to an analysis, and this has formed an integral part of the work of the station right through; further, every variety of cane introduced on the farm was similarly examined as to male fertility, whether it was used or not, and collections of arrows made from all parts of India where they appeared were also tested. And this collection led to fruitful results, in the following manner. It was found that arrowing was rare in North India and that, when it occurred, the stamens were almost invariably completely closed and no pollen was formed. This explained the former failure to raise seedlings in India, for all of the attempts had been made in Northern India with the solitary exception of the Samalkota one referred to above. Every arrow used on the farm is placed in tissue paper for subsequent examination; 200 stamens are shaken out and these are passed under a hand lens to see which are open, and the stamens are separated into three classes, open, partly open, and completely closed. The results have been kept in a special register. To illustrate the sterility of North India cane flowers the following details may be given of the Saretha variety, one of the few kinds which flower in North India. A set of arrows was received in 1915-16: those from Shahjahanpur (United Provinces), Sipaya and Sabour (Bihar), Jubbulpore (Central Provinces), had no open anthers at all; some received from Pusa (Bihar) had 4 per cent open, while those grown at Coimbatore have habitually over 90 per cent open. The frequency of flowering is illustrated by the following: in 1917, two canes flowered at Shahjahanpur, three at Pusa, six at Sipaya, six at Jubbulpore, 16 in Nagpur (south Central Provinces), 71 at Coimbatore.

Obtaining Crossed Seedlings at Coimbatore.

Large collections were now made of varieties of cane from every part of India, including both the indigenous canes used for gur making and the introduced thicker tropical varieties, grown everywhere but used in the north only for eating as a fruit, as they cannot usually be ripened for sugar making, and some 200 to 300 kinds were got together. But it was found that crossings were not very easy to obtain between these two classes, and the first successful batch of hybrids, obtained in 1912, was between a small North Indian cane and the wild *Saccharum spontaneum,* whose period of flowering is less limited than in cultivated canes. The North Indian canes were shy of flowering at first and, when they did so, it was noted that their pollen was infertile, whereas, curiously enough, the thick tropical kinds formed masses of healthy flowers, from which seedlings could be raised in any quantities here as elsewhere in the world. This raising of seedlings from thick canes was carried out for the first year or two, to obtain better varieties in South India, to gain knowledge on the subject and for the sake of practice, but the aim all along was to obtain crosses between them and the indigenous Indian canes.

The first problem was to make the canes to flower. The North Indian canes were at first obviously out of their element, and it was only later that, by altering their treatment, good healthy plants were obtained. Even then flowering was scarce among them on the farm plots, and a special study had to be made as to the cause of this. The flowering time was found to be strictly seasonal, usually

commencing in October and lasting about six weeks, an unfortunate time for study because this period synchronized with that of the northeast monsoon when over half the annual rain fell, accompanied by storms of wind which rendered the work of manipulating the arrows very difficult. Planting on the station was at the usual time, February to March, and the canes were reaped a year later, no arrows being formed. But it was found that, if the canes were planted in November, they flowered in the following October. Hence a series of "arrowing plots" were laid down, plant canes and first ratoons, and this part of our difficulty was solved. There are two classes of sugar cane land at Coimbatore—"dry," of a lighter nature and irrigated from wells and then termed "garden land," and "wet," very heavy clay irrigated for many years from tanks. The wet land had been created from the dry by this perpetual irrigation, through which the finer clay particles had accumulated during many years. It was noted that, in the wet land, canes planted as late as March or April would generally flower in October, and thus much of the earlier work was done with arrows collected from this source. The cane farm was chosen deliberately on the dry land, because this was more in keeping with the land of the sugar cane tracts in North India. The following figures of thick and thin canes flowering show the results obtained in our efforts at causing the canes collected on the farm to flower. The first figure in each year is of thick cane varieties and the second of thin:

1912, 3, 0; 1913, 0, 0; 1914, 5, 4; 1915, 35, 36; 1916, 62, 34; 1917, 83, 52, besides among our own selected seedlings, 183, 103.

The Effect of the Weather on Flowering.

It was soon noted that the mass of flowers produced was very different in different years, and a study of the rainfall showed that this was a factor of some importance. In North India the arrowing of the sugar cane varies a great deal, being rarer and rarer as the Punjab in the northwest is approached, and there it is unknown. In certain tracts it is recorded that the appearance of the arrows in the cane fields is regarded as a grave portent and whole villages are said to have been deserted from this cause, for fear of the drought and famine which followed in its train. Flowering is common in the Peninsula, but is much more abundant in the drier, western than in the moister, eastern regions. At Coimbatore, itself in a semi-arid tract, it was found that good rains during the growing season had a markedly beneficial effect on the number of arrows appearing. The wet land showed plenty of arrows and, on the farm, it was found of advantage to place the arrowing plots on places liable to be flooded in the rainy season. Here, then, we have two opposing views as to the effect of the weather on arrowing, and it is somewhat difficult to reconcile them. If we might hazard a solution, flowering is probably aided by some interference in the normal progress of growth, some check, whether from drought or waterlogging, and this is in general agreement with a practice in horticulture, for instance, in making azaleas to bloom freely by introducing them into pots too small for their free growth or in injuring fruit trees to make them fruit more abundantly. It may be noted that the reports from Natal indicate that the Uba cane flowered abundantly in places where the rainfall was deficient, thus falling into line with the North Indian experience.

We thus see that arrowing of the cane in India is affected by latitude, by the time and planting and by the character of the soil and its treatment, while the usefulness of the arrows for the production of seedlings depends in the first instance on their possession of abundance of opened anthers. Although enough data have not as yet been accumulated for clearing up the matter thoroughly, it is evident that the amount and character of the rainfall also have a direct effect. As we shall see later, the habit of flowering is a character of some importance in classification, the greatest diversity occurring among different canes in this respect.

The Determination of Female Fertility.

This is by no means an easy matter, and we have usually had to record the previous behavior of each variety in order ultimately to form an estimate of the chances of obtaining seedlings when using it as a mother. And we have learnt from our experience that the arrows vary as much in this particular as in the fertility of the male organs. Working along these lines it occurred to Mr. Venkataraman that the presence of starch grains, which had proved so useful in determining the fertility of pollen in the sugar cane, might also be shown in the stigma. This was proved to be the case, as far as the very extensive trials at present made can be taken as a guide. If the stigma and style have starch grains in them the probability is that the flowers are capable of producing seed and seedlings, but if there is no starch the chances are against it. This important discovery has lightened the work of crossing at the Cane-breeding Station very considerably of later years, by the avoidance of large numbers of crossings which would turn out useless, and concentrating on such as would, other things being equal, turn out successes.

Variations in the Time of Flowering.

Having thus at length obtained an abundance of arrows from different varieties of canes on the station, the path of progress was arrested by the annoying fact, which soon obtruded itself, that, within the limits of the season, the different varieties had their own particular time of flowering. The thick canes as a class flowered earlier than the thin; when the latter opened their flowers, most of the thick canes had faded or were at any rate past their prime and more or less useless for crossing. The following will give some idea of this phenomenon. Among the thick canes, Vellai, with often almost entirely closed anthers, leads the way, its flowers opening during the second and third week in October; Karun, Chittan and Kaludai Boothan follow; then D. 74, Mauritius 16 and Java and, in the middle of November, Pachrangi and Moradabad. The thin canes are led by the Pansahi group, also generally devoid of open anthers, at the end of October, then the Saretha group commences flowering, and these are followed by the Nargori and Mungo groups. It thus happens that Vellai with its male sterility is over before the Saretha group comes in with its masses of fertile pollen, whereas the Pansahi group is obviously useless for this crop because of its own male sterility. These and similar difficulties have constantly hampered us in our efforts at obtaining the much desired crosses, for a good mother, that is one that has no good pollen, is rare and obviously of great value. There is some

evidence that in many cases there is prepotency of the pollen in its own flowers and, in numberless experiments of dusting foreign pollen on arrows with male fertility, no trace of the foreign blood has been observable, although it is only fair to say that important exceptions occur and the method has its value. In these circumstances we have turned to whatever arrows were available, and there is one set of our seedlings which has been of the greatest service. It has all along been observed that, in every large batch of thick cane seedlings, a very small proportion show remarkable differences from the usual type. These seedlings have strange forms, quite unlike the parents or any cane growing on the farm; they are immensely vigorous but have low sucrose content, are in fact in some respects more like the indigenous Indian canes than seedlings of thick canes. They have the power of producing masses of flowers which are specially fertile, yielding great numbers of seedlings, and which when selfed show no approach to their thick ancestors but remain true to the new type. These we have called "rogues." They differ from the other canes growing, in that they flower early, and are thus available for crossing with Vellai and indeed most other thick canes as mothers. It was at first thought that they might be accidental crosses between the thick and thin canes, but they have again and again appeared before any of the latter are in flower. And a similar use has been made even of the wild canes, which are less strictly limited in their periods of flowering. Thus *Saccharum Narenga* begins to flower a good deal earlier than Vellai and continues so to do throughout the flowering season, and a fine series of crosses were obtained between these two. Narenga is a grass and does not form a solid cane, and the crosses show canes varying from one to six feet in length (Plate I). But all attempts to make further use of these seedlings have been unsuccessful for, although they are profuse in flowering, they are absolutely sterile both in the male and female organs. The difference between the parents in this cross is too great, and they are apparently all of them "mules." But by crossing Vellai with *Saccharum spontaneum* some very useful seedlings have been obtained, certain of them sent to the Punjab giving a very good account of themselves. Meantime, the most various devices have been adopted to retard the early flowering of the thick and hasten the late appearance of the thin canes, with the result that some of the latter have been hurried up, and a number of crosses formerly unobtainable have now been secured.

Degree of Development of the Arrows in Different Canes.

The different varieties and groups of canes show great diversity in this respect, more so indeed than in the times at which they flower. We have all stages, from some which have never been known to arrow and have not done so with us, through those that are beginning to yield to treatment and up to such as readily produce masses of fertile flowers on the least provocation. The fullest development of arrows is found, somewhat strangely, in various highly developed thick canes, as well as the most primitive class of the Indian indigenous ones, these forming the extremes in sugar cane evolution. The latter are typical of the Punjab and it is fairly safe to say that most of these have never flowered since they were first introduced to cultivation there, for canes have, I believe, never been known to flower in the Punjab. While it is natural to sug-

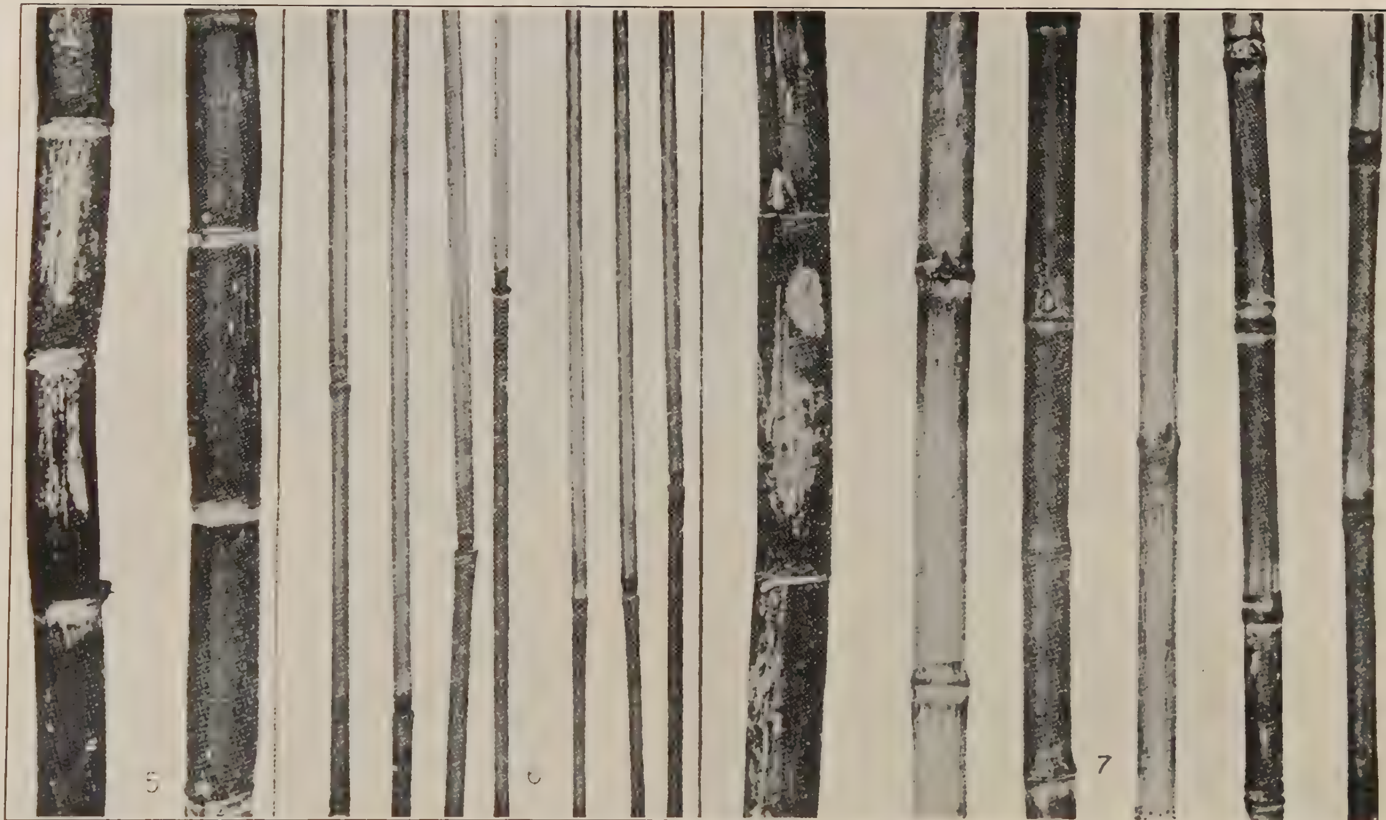


Plate I. Vellai x **Saccharum Narenga** (1913-15). Canes of parents and seedlings.

5.—Two Vellai canes. 6.—**Saccharum Narenga** "Canes." 7.—A selection of the canes of the resulting crosses, from the thickest to the thinnest, one average cane from each of six seedlings.

gest that this readiness to flower in these primitive canes may be connected with their nearness to the wild state, this cannot be assumed with regard to the rich and highly developed forms which show equal readiness to flower. Many of the North Indian canes have been induced to flower on the farm for the first time within knowledge, some of them it is true in a very half-hearted way, but it is legitimate to hope that, with further study, the tardy and at present infertile members may some day produce flowers which will add to the range of our crosses. Each such form has some good points, whether in erectness, or short and sturdy habit, self-cleaning or drought resistance, and it would be of advantage if these could be added to our list of useful characters in the field.

The great Saretha group heads the list in producing masses of flowers from which any number of seedlings can be raised; the group has, however, its defects. Its members are liable in a greater or less degree to be infected by smut, and this is a very serious disease in certain important sugar tracts in North India. It may be noted that some of the Java seedlings with a male parentage of members of this group are similarly liable to smut. A second fault, shared it is true by others, is that the selfed seedlings are as a rule of very inferior character, many of them mere tufts of grass; one indeed was found crawling along the surface, with stems 20 feet in length and the thickness of a lead pencil, and never raising themselves off the ground. The seedlings thus far raised have juice very inferior to that of their parents. In one year 700 strong seedlings were raised by selfing Saretha, the type variety and perhaps the best all round variety of the group. These were grown to maturity in the vain hope of obtaining one or two which had good habit and juice of a better purity than that of the parent, but nothing was gained by the experiment. The Sunnabile group flower sparsely, and very few of them produce seedlings. The varieties of the Pansahi group, of which Uba is a member, produce enormous masses of beautiful large arrows but, as a general rule, these are made sterile and hitherto the crosses have not been of special value, excepting perhaps in general vigor and good habit, in which character they resemble their Pansahi parent. The juice is usually not good as far as I remember. In the Nargori group the arrows are deformed and the flowers ill-formed, often only half protruded. The Mungo group does not appear to be likely to be of much use in crossing, much as this is to be desired; the arrows when they are formed rarely protrude from the sheaths, forming inside the merest rudiments of flowers. In the thick cane group, there are all stages from complete sterility to abundant seedling production, and, in the latter case, all stages of robustness have been noted. In one case out of 4000 apparently healthy seedlings it was only possible to raise two, although the greatest care was taken of them in all stages. A mass of information can be extracted from the carefully kept office registers in the Cane-breeding Station on these and similar points. All attempts at selfing good seedlings have been given up, on account of the generally inferior nature of the resulting second generation of seedlings. The arrows of different kinds of cane are often very different in form as well as in fertility, and this fact has been of use on several occasions in disentangling the different arrows where the kinds have been growing close together in a crowded field. Several errors in classification have also been cor-

Plate II.—Vellai x **Saccharum Narenga.** Arrows of the parents and of a typical cross.

rected by noting the time of protrusion of arrows and their form when protruded. Perhaps the most interesting case of these differences is that met with in the crossing of Vellai by *Saccharum Narenga*, where the arrows of the seedlings are obviously in many respects half-way between the very different ones of their parent. This is shown in Plate II.†

[J. A. V.]

German Potash Mines.*

THE POSSIBILITY OF FINDING POTASH DEPOSITS IN THIS COUNTRY.

By Robert G. Skerrett.

Potash in the decades gone, when soft soap was a common commodity in the household and not the synonym for conversational blandishments, was generally got from wood ashes subjected to a simple leaching process. The very term potash is a word picture of the way in which the alkaline liquor was boiled down and concentrated. At that period in our development, potash so obtained served as an essential ingredient not only in the preparation of a laundering aid, but it figured in the manufacture of glass, powder, etc. Farmers knew that their crops were likely to be more abundant if they burned over the dry vegetation of their fields or scattered wood ashes broadcast upon their acres; but only a few husbandmen were aware that a measure of potash was indispensable to their crops and needed proportionately more by some than by others.

Potash, or potassium as it is technically named, has assumed a position of prime importance in the economy of modern life far beyond that imagined half a century ago. Not only is the stuff required in the making of glass, as a source of nitrate in the explosive industry, and as a base for cyanide so widely employed in metallurgical activities, but the sulphate and the chloride of potassium are outstanding factors in the manufacture of so-called artificial fertilizers. Finally, to a lesser degree, but likewise invaluably, potassium salts are used in dyeing, tanning, electroplating, photography, medicine and as chemical reagents for a variety of purposes.

Just what potash means to us can be gathered from the fact that up to the outbreak of the World War we imported from Germany, our principal foreign source of supply, substantially a million gross tons of the salts each twelve months; and probably about 90 per cent of that material was devoted to the enriching of our cultivated soil. There are three plant foods of outstanding significance—phosphorus, nitrogen, and potassium, and the last serves to promote stalk strength and a more generous kernel filling in a growing plant. Fields

† Plates I and II are reproduced by kind permission of the Agricultural Adviser to the Government of India, from C. A. Barber, "Studies in Indian Sugar Canes," No. 2. Memoirs of the Department of Agriculture in India, Botanical Series, Vol. VIII, No. 3, July, 1916.

* Scientific American Monthly, Feb., 1921, pp. 151-154.

denied a sufficient quantity of potash yield crops of an impaired and sometimes an unmarketable character; and the best proof of this is what happened in our farming districts when cheap potash from the mines in Prussian Saxony was cut off from us by reason of the conflict in Europe.

According to testimony given before a Congressional committee in 1919, the lack of potash had a serious effect upon our cotton, potatoes, onions, citrus fruit, and garden truck, and this largely because the commodities were deficient in that strength needful to enable them to withstand transportation and to keep them fit until sold. As one prominent farmer from the South explained it, "If there is not enough potash in the soil, I get a plant that is so sappy and tender that it won't bear transportation. And to get that plant sufficiently woody

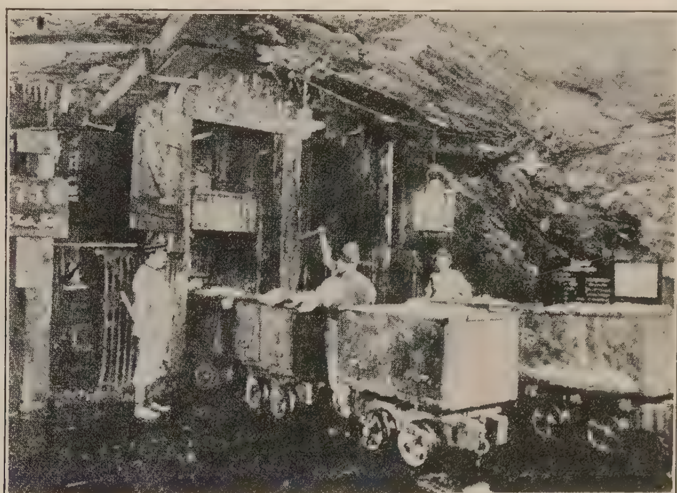
In the heart of a potash mine at Stassfurt 2600 feet underground where temperature is 104 degrees F.

and strong to bear a long trip we have to use from 10 to 14 units of potash per acre." A unit is 20 pounds of pure potassium oxide. Time and again, peaches, strawberries, cabbages, beans, cucumbers, etc., which appeared all right when picked, would spoil or fall below standard by the time they reached a far-off city, and that in spite of refrigeration en route. Ground that would ordinarily give a crop of 80 barrels of potatoes to the acre would yield only 11 barrels and even then the tubers were not up to the usual size.

With cabbages, potatoes, and onions constituting the principal vegetable items of the dietary of the vast majority of our people, and with cotton forming the fiber for that textile used in such vast quantities by both the rich and poor of the nation, it is not hard to visualize how vital to our well-being is an abundance of low-priced potash. When the German potash deposits were first exploited sixty-odd years ago, and the mining of those beds proved a simple and fairly inexpensive operation, the agricultural world breathed freer; for the geolo-

gists proclaimed that there was enough of the alkali tucked away there under ground to meet the demands at home and abroad for centuries to come.

These mines are located near Stassfurt, and were discovered by the Prussian Government in 1843 while boring for rock salt. For some years no attention was paid to the potash, which was brought up to the surface and cast aside. But afterwards, when it was found that potash was essential to the stimulation of crop production, the value of the neglected piles of mine waste dawned upon the Teutons; and out of that awakening developed the well-known Kali Syndikat which became all-powerful in the international distribution of those potassium salts. This was made possible by the fact that the Germans could mine, ship across the ocean, and deliver the potash at the ports of our Atlantic seaboard at an average price of from seventy to eighty cents per unit of pure potassium.



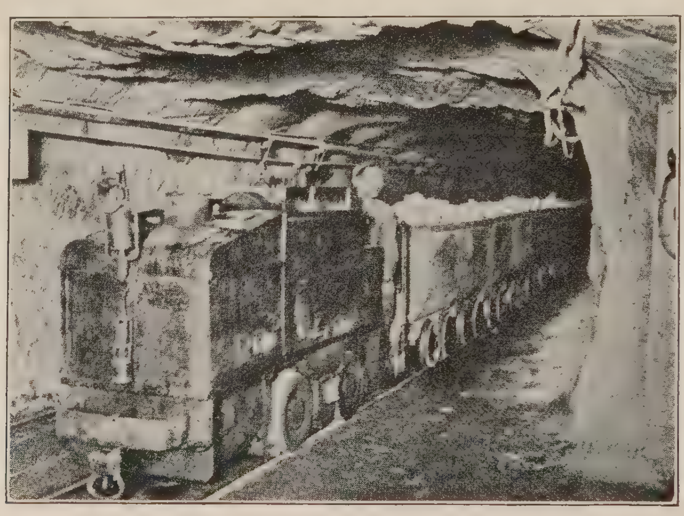
Loading an elevator at the bottom of a shaft 2500 feet below the surface.

The Stassfurt salt beds, with their interposed layers of potash, were deposited there in the Quaternary Age of this globe of ours, when the present plains of northern Germany lay deep beneath a briny ocean. In the course of time, using the term in the ampler geological sense, the potash separated from the salt and was precipitated in the form of strata or pockets. This process has a great deal of significance to us in view of the fact that vast deposits of salt, likewise the relics of a sea that evaporated eons back, lie far below the ground level in a widespread area extending north and south throughout certain of our Central States. A similar condition probably exists elsewhere upon this continent of ours; but the revelations in question have been made by borings driven in search of petroleum.

In 1914, prior to hostilities, the German potash industry at Stassfurt was centered about 187 shafts, and the operating force numbered 35,000 people. It is said that quite $250,000,000 has been spent in developing the properties, and that the mines are capitalized at substantially $380,000,000. An official of the U. S.

Bureau of Mines has lately visited the region and has reported that the "Stassfurt potash occurs as potassium chloride or potassium sulphate or both salts intimately mixed with salts of sodium, magnesium and lime, and contaminated with substances insoluble in water, such as ferric oxide, clay, etc. The potash salts are segregated in more or less extensive pockets throughout the salt mass. * * * The main potash region is a stratum varying from 30 to 150 feet in thickness and at a depth requiring shafts of 5000 feet." It should be evident that the raw product is of a mixed nature, and when sold as such is valued according to the percentage or number of units of pure potassium which the stuff contains. On an average this is in the neighborhood of about twelve per cent of pure potassium.

According to the German laws, each mine must have at least two shafts—one for ventilation and one for active operation. These shafts are placed from 500



A train of cars or buggies loaded with potash drawn by an electric locomotive.

to 1000 feet apart and are connected underground. This arrangement insures that the air drawn down one shaft shall, after circulating through the several mine passages, ascend by the other shaft and thus carry off the vitiated atmosphere. The duplication of shafts further provides a means of escape for the workmen in case one of the shafts is closed by accident. It is the practice to line the shafts from top to botom with iron, concrete or wood, according to the local needs and the availability of the materials mentioned. The shafts average about 16 feet in diameter.

As might be expected, water reaches the shafts by reason of seepage working through at the upper levels. This water drains down into sumps at the foot of the shafts, whence it is forced surfaceward by pumps. The mines are otherwise dry. Because inflammable gases appear only infrequently, the miners work by the light of bare flames, using generally a rather common type of acetylene lamp. The danger of unexpected gassing is neutralized by the action of

blowers, which are kept running close to the points where the men are at work. The potash is blasted out at the face of the headings and freed in this manner in big masses. The needful holes for the explosive charges are made with electric drills and augers. The material is then broken up by the miners into good-sized lumps—using picks and heavy hammers for the purpose. At the same time the laborers separate the low-grade material for that of commercial value, and the rejected stuff is used, as occasion requires, to fill up abandoned workings.

The potash is transported from the headings by electrically-drawn trains made up of small iron cars or "buggies," and moved by rail to the elevators located in the shafts. These lifts are functioned by a mechanical contrivance that insures a nice control of their speed. There are two counter-balancing elevators in a shaft, and this interrelation has much to do with the safety of their service. Each lift is a double-deck structure which can accommodate from six to eight of the mine cars; and when working to capacity it is practicable to send to the surface between 800 to 1000 tons of the raw potash daily by way of a single shaft.

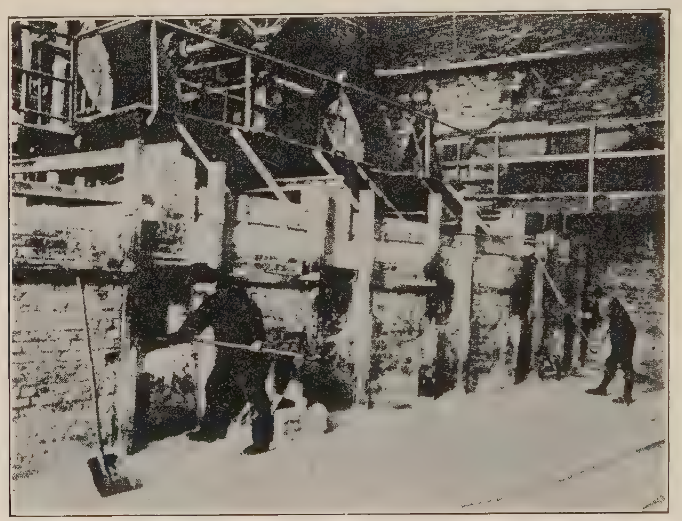
Upon arriving above ground, the buggies, with their burdens, are run upon a platform where they are caught and held while being tipped over to effect discharge, and the crude salt drops by way of a chute into a power-driven crusher located below. From the crusher the substance may be dealt with in two ways, i. e., it may be ground into bits, having a maximum dimension of a quarter of an inch, and then removed to storage awaiting shipment, or the granular material may be sent to a refinery, frequently nearby. Here, trained operatives sort out further the relatively high-grade from the low-grade potash. The latter is passed on to a grinding mill, where it is mixed with raw salts, and the better grade is carried to another grinding mill and from it dropped into an elevator that transports it to the storage bin preliminary to undergoing additional treatment.

According to the report of the representative of the U. S. Bureau of Mines, who visited the European mines, analyses showed a raw salt averaging 15.6 per cent potassium oxide, while the rejected or low-grade material contained 5.8 per cent K_2O. As he explains: "The latter being added to the raw salt or 'stock kainite' brought its potash content down to 14.3 per cent, while the rich salt for the refinery was brought up to 18.6 per cent K_2O." The procedure in the refinery rests on the fact that if a solid mixture of the chlorides of potassium and sodium be brought in contact with a saturated solution of the same salts, and the combination be then heated, this treatment will induce the precipitation of a greater amount of solid sodium chloride and effect the while a further solution of a considerable percentage of potassium chloride. By properly handling thereafter the masses of brine and solid salt it is feasible to accomplish the complete recovery of the potassium chloride in any desired degree of purity.

The actual working of the process commercially is as follows, according to the authority just cited: The rich salt, so called, is fed into one end of a trough, made of sheet iron, and the boiling-hot brine enters at the other. The trough is fitted with a screw device which thoroughly stirs the mass and gradually drives the solid contents toward the opposite end of the trough and against the oncoming flow of the liquid. The trough is equipped with steam pipes which

enable the temperature of the mixture to be raised as high as 230 degrees Fahrenheit. The solids in the trough or dissolver are removed by a screw-like elevator, washed, drained, and piled, until sufficiently air dried, when they are either returned to the mine to fill abandoned passages or are sold for crude sodium chloride. The washings are added to the mother liquor and used for subsequent dissolving operations. The hot brine from the trough is led to settling tanks, where the temperature falls slightly below the boiling point, and the somewhat clarified liquor is thence siphoned to the crystallizers. The residue in the settling tanks is drawn off, and drained more or less imperfectly, and the drippings are added to the mother liquor—the solids, for the most part clay, being discarded. The residue, amounting to from 6 to 8 per cent of the product as it comes from the mines, carries probably 1.5 per cent of potash. It seems that the loss of potash in the residue is but little more than 1/10 of 1 per cent.

Crystallizers are nothing more pretentious than flat iron boxes about 2 feet



Calcining ovens in which the potash salts are thoroughly dried out.

deep and large enough to hold approximately 6000 gallons of the brine solution. Three days are commonly required to bring the temperature down to 50 degrees Fahrenheit. Each "pan" will yield better than 3 tons of crystallized potassium chloride; and a plant equipped with 72 crystallizers, working in three groups of 24 units, will turn out an average of 80 tons of finished salt every twenty-four hours. The mother liquor is used over and over again. The Germans have done this for 12 months' running—discarding the liquid only when it became too highly charged with magnesia and other impurities to make it serviceable. For a plant of 72 crystallizers, the coal burned, exclusive of that for the generation of electric current, has been at the rate of 13 tons per day in the refinery, and probably about 7 tons additional for general purposes in the mine, the plant, and office.

The potash deposits in Alsace, which are now in the hands of France, were

only moderately exploited by the Germans prior to the World War, and they were tapped by but 17 shafts. The beds were discovered six miles northwest of Mulhouse, as recently as 1904, during exploratory borings for oil. The first mining shaft was completed in 1909 and production started in 1910. In 1913, 40,707 tons of K_2O were procured from that source. The Alsatian deposits differ notably in physical and chemical characteristics from those in Saxony. The lower layer lies at an average depth of but 1800 feet, and constitutes a fairly continuous stratum, composed of a mixture of potassium and sodium chloride, extending over an area of upward of 77 square miles and having a mean thickness close to 11.5 feet. Twenty feet above this layer is a parallel but less extensive bed, ranging 4 feet through. Both beds are pretty commonly banded with blankets of clay, and these vary in thickness from a fraction of an inch to several inches. The upper deposit is deemed less important, and is looked upon as a reserve which can be worked later on. The volume of the two layers is estimated to be 1,350,000,000 cubic yards, calculated to contain in the neighborhood of 1,500,000,000 tons of salt or 275,000,000 tons of pure oxide of potassium—enough to meet the world's demands for possibly two centuries. The Stassfurt beds, on the other hand, are said to contain fully 2,000,000,000 metric tons of K_2O—sufficient to meet man's requirements for 2000 years at the normal rate of consumption.

The World War brought America face to face with the possibilities of a grave potash shortage. The year before the outbreak of hostilities our importers were paying less than $90 a ton for pure potassium oxide, and before the close of 1917 domestic potash, at the plants of fertilizer manufacturers, was fetching $560 a long ton! This was derived from original sources such as alunite, the brine of certain of our highly alkaline lakes in some parts of the country, kelp, and as a by-product of the cement industry, from wood ashes, molasses distillery waste, beet sugar refineries, etc.

By dint of very commendable enterprise and outlays totalling, so it is authoritatively declared, substantially $40,000,000, patriotic citizens embarked upon the upbuilding of a domestic potash industry. The natural salts or brines from Searles Lake, California, and the lakes in northwestern Nebraska, were the principal origin of the much-desired potash obtained here after we were thrown back upon our own resources. In 1918, it was from Nebraska that we secured approximately 60 per cent of the potash produced within our borders. The section is known as the sand-hill district of Nebraska, where foliage is commonly lacking, although the soil in the valleys is fairly well cloaked with a growth of grass.

Within that region lie, in round numbers, 3000 lakes ranging in size from modest ponds to bodies having an expanse of 600 acres. The depths of these waters run from 1 to 6 feet, and virtually 10 per cent of them are decidedly alkaline, and fully 150 of these ponds and lakes carry a high percentage of potash. The richest brines are in the bed mud and sands, and these extend downward for from 15 to 40 feet. The brines are readily obtained by pumping operations. The productive area beneath the several lakes differs greatly. That is to say, it has been found to underlie a large part of some lakes and yet, as a rule, only

a small proportion of the subsurface sands have yielded brines in commercial quantities.

A very significant feature in connection with these Nebraskan fields has been the results realized from a few wells sunk in valleys more or less distant from the lakes. The quality of the brines brought to the surface have suggested that the productive region may possibly reach far beyond the lakes themselves and may even exist in localities where there are no lakes at all. Nineteen companies have operated in Nebraska, and during their activities developed capacities ranging from 3 to 200 short tons of crude potash salts daily. Inasmuch as the total quantity of potassium in these beds is rather speculative, their potential value cannot be determined. However, one investigator has put the recoverable underground supply at 100,000 tons of K_2O.

From Searles Lake, California, we secured the second largest output of domestic potash, viewed as a single source, in 1918. The production was nearly double that of the year before; and the salts contained from 60 to 70 per cent of potassium chloride and about 15 per cent of borax. In the process of manufacture, after recourse to partial evaporation to remove a part of the associated salts, the brine is drawn off and allowed to cool—this procedure serving to precipitate the marketable potash. Estimates seem to indicate that Searles Lake contains the equivalent of 20,000,000 tons of actual potash in a saturated brine associated with soda, borax, salt, and sodium sulphate. The proportion of potash in the dried salts is about 7.2 per cent. In the German and Alsatian deposits the K_2O content ranges from 12 to 20 per cent.

Potash obtained from alunite in 1918 amounted to 6180 short tons, containing 2621 tons of potassium oxide, then valued at $1,276,774 at the point of shipment, i. e., $4.87 per unit of K_2O. The entire output was derived from the alunite deposits in the vicinity of Marysville, Utah. Unfortunately, the quantity of alunite available for potash is not known. From such of our cement mills as are equipped with potash recovery plants we secured, in 1918, 12,652 short tons of crude potash, containing 1549 tons of K_2O. And from our blast furnaces and silicate rocks we got a matter of 310 short tons of potassium oxide. Kelp supplies us with 4804, molasses distillery waste 3467, beet sugar refineries 1374, and wood ashes 673 short tons of K_2O.

What store of potash may still be hidden underground in the United States is quite unknown, but inasmuch as potash is associated in Alsace and Saxony with the salt beds of prehistoric seas, there is ample reason to believe that similar occurrences here may be indications of a like if not a greater wealth of subterranean potassium.

Doctor George Otis Smith, Director of the U. S. Geological Survey, has said: "We have been searching for potash on a very small, even a picayune, scale. For instance, there may be and probably are certain points in our underground deposits of salt where conditions were favorable for potash to be deposited. We have put down one hole in an area of 98,000 square miles, which is like taking just one look in a hay mow for a missing needle."

[H. v. I.]

SUGAR PRICES FOR THE MONTH

Ended May 14, 1921.

	96° Centrifugals Per Lb.	96° Centrifugals Per Ton.	Beets Per. Lb.	Beets Per Ton.
Apr. 19, 1921	5.635c	$112.70	No quotation	
" 21	5.325	106.50		
" 22	5.02	100.40		
" 26	4.89	97.80		
" 27	4.88	97.60		
May 4	4.64	92.80		
" 5	4.6167	92.334		
" 9	4.76	95.20		
" 10	4.89	97.80		
" 11	4.885	97.70		
" 14	5.02	100.40		

[D. A. M.]

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